Vol. 62

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PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

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Volume 62
1952

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BENJAMIN MOULTON, EDITOR

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Spring Meeting
May 23-24
INDIANA DUNES STATE PARK

Fall Meeting
October 16-18
VALPARAISO UNIVERSITY

Published at Indianapolis, Indiana
1953

1. **Instructions for Authors** appear at end of this volume, p. 331.

2. **Exchanges.** Items sent in exchange for the Proceedings and correspondence concerning exchange arrangements should be addressed:

Indiana Academy of Science, Library
c/o State Library, Indianapolis 4, Indiana

3. **Proceedings** may be purchased through the State Library at $3.00 per volume.

4. **Reprints of technical papers** can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

5. The Constitution and by-laws reprinted from v. 62 and the Membership list reprinted from v. 61, are available to members upon application to the State Library, Indianapolis, Indiana. Necrologies reprinted from the various volumes can be supplied relatives and friends of deceased members by the Library.

6. Officers whose names and addresses are not known to correspondents may be addressed care the State Library. The address of the editor of the present volume is Dept. of Geography, Butler University, Indianapolis, Ind.

TABLE OF CONTENTS

Officers and Committees for 1952 6
Minutes of the Spring Meeting 9
Minutes of the Executive Committee 11
Minutes of the General Session 17
Constitution of the Indiana Academy of Science 19
New Members of the Year 1952 25
Junior Academy of Science 28
Necrology 34
Presidential Address—P. D. Edwards 45

Anthropology

Abstracts of papers not published in full 52
V. R. Helmen—New Material from Marion County, Indiana 53
H. E. Driver—The Acorn in North American Indian Diet 56

Bacteriology

Abstracts of papers not published in full 63
R. G. Murray—Time lapse cinephotomicrography of tissue cultures .. 67
J. D. Ebert—The development and role of p-Aminobenzoic acid in the early chick embryo 72
C. W. Hagen, Jr.—Applications of plant tissue culture 81
R. N. Hull—Newer methods and practical applications of tissue culture 87
R. L. Thompson—Factors affecting growth of mammalian viruses *in vitro* 92
E. Weiss—Counting infectious viral particles in tissue culture 95

Botany

Abstracts of papers not published in full 98
Indiana Plant Distributions Records, XIII. 1952 108
H. R. Youse—A taxonomic study of sixty pollen grains collected by honey bees 114
W. H. Welch—Studies in Indiana Bryophytes, X 122
J. E. Potzger and L. Chandler—Oak forest in the Laughery Creek Valley, Indiana 129
K. A. Wagner—Notes on Indiana Liverworts, V 136
W. W. Bloom—Effect of aging on the viability of sporocarps of *Marsilea quadrifolia* 139
J. O. Cottingham—Higher fungi of Marion County, Indiana 143

Chemistry

Abstracts of papers not published in full 144
W. G. Kessel—A mine water problem 147
J. M. Christens—Reinforcement of natural rubbers by fillers 150

A. W. MEIBOHM—Some analytical uses of 3-Dimethylaminopropylamine 156

J. H. BILLMAN and R. V. CASH—The alkylation reaction of Gabriel Synthesis 158

R. B. FISCHER and D. J. FISHER—An oscillographic method for the study of solution behavior of radio frequencies 160

A Symposium of Papers on the Teaching of Chemistry 166

- E. L. HAENISCH—The relationship between teaching of chemistry in the secondary schools and in the colleges and universities of Indiana 166
- E. E. WEAVER—Work of the Northeastern Ohio Chemistry Teachers Organization 166
- F. C. SCHMIDT—Preparation for college chemistry 167
- R. A. BENKESER—Findings of a Purdue committee on how to stimulate interest in young students to choose a career in chemistry 167
- NED GUTHRIE—Comments on teaching chemistry in high school and college 168
- E. W. GROSS—Comments by a secondary school teacher 169

Entomology

Abstracts of papers not published in full 170

F. N. YOUNG—The approach to taxonomic problems 172

J. J. DAVIS—Insects of Indiana for 1952 176

M. C. WILSON and R. L. DAVIS—Studies on chemical control of insects affecting alfalfa seed production 181

E. L. MOCKFORD—Additional notes on Indiana Psocoptera 198

B. E. MONTGOMERY—Notes and records of Indiana Odonata, 1951-1952 200

H. O. DEAY—The periodical cicada *Magicicada septendecim* (L) in Indiana 203

J. R. MUNSEE—A preliminary report on biometrical studies on *Tropisternus striolatus* (LeConte) and *T. mexicanus* (Castelnau) 207

P. W. BERG—Some laboratory experiments on resistance of the Pomace Fly to DDT poisoning 211

R. T. EVERLY—The effect on the lesser clover leaf weevil on the seed yields of mammoth red clover 217

Geology and Geography

Abstracts of papers not published in full 223

C. L. BIEBER—Current directions indicated by cross-bedding in deposits of Early Mansfield Age in southwestern Indiana 228

S. S. VISHER—Indiana's weather: some extremes and advantages 230

F. E. KOTTLOWSKI and J. B. PATTON—Pre-cambrian rocks encountered in test holes in Indiana 234

P. MCGRAIN and M. L. MITCHELL—Geologic characteristics of Indiana streams 244

T. F. BARTON—Cities with a population decline in southwestern Indiana, 1940-1950 250
L. E. BRACKEN—Some geographical factors in a quarter century of Indiana harvests, 1926-50 256
FLOY HURLBUT—Our highways, an Indian heritage 266
R. L. GENTILCORE—Curves of population change in Indiana, 1850-1950 272

History of Science

Abstracts of papers not published in full 277
R. E. GIRTON—Pioneer microscopists of the seventeenth century 281
W. E. EDINGTON—William Ephraim Heal, Indiana pioneer mathematician 287

Physics

Abstracts of papers not published in full 290

Psychology

Abstracts of papers not published in full 292

Zoology

Abstracts of papers not published in full 297
F. R. ELLIOTT—The Araneology of Indiana 299
J. J. KLENNER—Histological effects of itrumil, thiouracil and thiourea on the endostyle of *Lampetra lamottenii* 318
P. L. KNIGHT—In vitro survival time of swine lungworms 319
J. D. MIZELLE and J. A. BERBARIAN—Developmental rate of the sheep stomach worm, *Haemonchus contortus* 320
R. M. COLEMAN—Histochemical demonstration of vitamin C in *Hymenolepis nana* var. *fraterna* 321
L. H. MONACO—Effect of cyanide on the oxygen consumption of developing ova of *Ascaris lumbricoides* var. *suum* 323
R. J. SHAVER—The effects of —10°C. and —16°C. on the viability and infectivity of *Trichinelia spiralis* larvae 325

Appendix

Instructions for Contributors 331
Index for Volume 62 333

OFFICERS AND COMMITTEES FOR 1952

OFFICERS

President	P. D. Edwards, Ball State Teachers College
Vice-President	H. M. Powell, Eli Lilly and Company
Secretary	W. A. Daily, Eli Lilly and Company
Treasurer	F. J. Welcher, Indiana University Adult Education Center
Editor	A. A. Lindsey, Purdue University
Press Secretary	Benjamin Moulton, Butler University

DIVISIONAL CHAIRMEN

Anthropology, Mrs. George F. Martin, Evansville
Bacteriology, R. C. Bard, Indiana University
Botany, H. R. Youse, DePauw University
Chemistry, E. L. Haenisch, Wabash College
Entomology, F. N. Young, Indiana University
Geology and Geography, T. Barton, Indiana University
History of Science, R. E. Girton, Purdue University
Mathematics, E. Hopf, Indiana University
Physics, Arnim Hummel, Ball State Teachers College
Psychology, L. M. Baker, Purdue University
Zoology, F. R. Elliott, Valparaiso University

EXECUTIVE COMMITTEE

(Past Presidents, Current Officers, Divisional Chairmen, and Chairmen of Standing Committees)

L. M. Baker, R. C. Bard, T. Barton, N. M. Coats, W. A. Daily, J. J. Davis, C. C. Deam, E. F. Degering, W. E. Edington, P. D. Edwards, F. R. Elliott, H. E. Enders, R. C. Friesner, R. E. Girton, E. L. Haenisch, C. B. Heiser, E. Hopf, W. H. Johnson, T. K. Just, J. S. Karling, A. A. Lindsey, R. W. Lefler, Eli Lilly, J. F. Mackell, M. S. Markle, Mrs. G. F. Martin, M. G. Mellon, A. H. Meyer, H. H. Michaud, W. P. Morgan, B. Moulton, F. Payne, C. L. Porter, H. M. Powell, R. R. Ramsey, D. Roller, S. S. Visher, F. N. Wallace, Paul Weatherwax, Winona Welch, F. J. Welcher, F. N. Young, H. R. Youse, T. G. Yuncker, C. M. Zieman.

BUDGET COMMITTEE

(President, Secretary, Treasurer, Editor, and Chairmen of Committees on Junior Academy, Library, Program and Relation of Academy to State)

P. D. Edwards, W. A. Daily, F. J. Welcher, A. A. Lindsey, H. H. Michaud, N. M. Coats, A. H. Meyer and F. N. Wallace.

COMMITTEES ELECTED BY THE ACADEMY

Trustees of the Academy Foundation (term four years): Chairman, R. N. Harger, Indiana University School of Medicine, Indianapolis (term expires 1952); Ward J. Rice (term expires 1955).

Bonding of Trustees (elected annually): Chairman, R. C. Friesner, Butler University; Scott McCoy.

Research Grants (term five years): Chairman, T. G. Yuncker, DePauw University (term expires 1954); W. H. Johnson (1952), M. G. Mellon (1955), Paul Weatherwax (1956), Mason Hufford (1953), P. D. Edwards and W. A. Daily (ex officio).

STANDING COMMITTEES

(Appointed by the President, Chairmen named first)

Auditing: Chairman, W. P. Morgan, Indiana Central College; S. E. Elliott.

Biological Survey: Chairman, C. B. Heiser, Indiana University; W. P. Allyn, W. B. Barnes, H. J. Brodie, F. K. Daily, H. O. Deay, S. D. Gerking, H. H. Michaud, Winona Welch, Frank Young.

Index: Chairman, Ray C. Friesner, Butler University; N. M. Coats, F. N. Wallace, Paul Weatherwax.

Indiana Science Talent Search (a sub-committee of the Junior Academy Committee): Chairman, R. W. Lefler, Purdue University; W. H. Welch, L. H. Baldinger, T. W. Torrey, P. D. Edwards, Walter Leckrone (ex officio).

Invitations: Chairman, John S. Karling, Purdue University; M. S. Markle, O. B. Christy, Naomi Mullendore Hougham.

Junior Academy: Chairman, H. H. Michaud, Purdue University; Walter Carnahan, N. E. Adams, R. Niswander, R. McDougal, J. E. Potzger, J. L. Cooprider, P. L. Whitaker, R. E. Martin, R. Cooper.

Library: Chairman, N. M. Coats, State Library; R. C. Friesner, W. G. Gingery, Glenn Black.

Membership: Chairman, R. E. Girton, Purdue University; Rev. C. P. P. S. Baechle, Juna Beal, S. R. Esten, M. R. Garner, D. G. Graam, W. H. Headlee, G. H. Hennion, C. P. Hickman, R. L. Hicks, L. B. Howell, Z. D. Hurlbut, J. L. Hyatt, C. E. Kaslow, M. W. Keller, E. Kintner, G. D. Koch, D. E. Miller, A. Strickler, W. E. Thrun.

Necrologist: W. E. Edington, DePauw University.

Nominations: Chairman, Paul Weatherwax, Indiana University; R. C. Friesner, M. G. Mellon, W. P. Morgan.

Program: Chairman, A. H. Meyer, Valparaiso University; Benjamin Moulton, Frank R. Elliott, E. J. Buls, R. G. Larson, A. R. Thomas, R. C. Waldschmidt, Carl H. Krekeler.

Publication of Proceedings: Chairman, A. A. Lindsey, Purdue University; R. C. Corley, Paul Weatherwax.

Relation of Academy to State: Chairman, F. N. Wallace, State Department of Conservation; J. A. Clark, H. J. Reed, Eli Lilly.

Representative on Council of the A.A.A.S.: Willis Johnson, Wabash College.

Resolutions: Chairman, T. G. Yuncker, DePauw University; T. W. Torrey, R. L. Shelley.

MINUTES OF THE SPRING MEETING

INDIANA DUNES STATE PARK

DUNES HOTEL

MAY 23-24, 1952

President P. D. Edwards called the Executive Committee meeting to order at 4:45 P. M. in the Dunes Arcade Hotel.

The officers and committees reported as follows:

Treasurer. Frank Welcher gave a report which will appear in Vol. 61 of the Proceedings.

Editor. Alton A. Lindsey reported that all galley proofs had been returned to the printer and that Vol. 61 was within the budget.

Library. In the absence of Chairman Nellie Coats, Ray C. Friesner read her report as follows: At present, 696 titles are received. As a courtesy to the Academy, the Indiana State Library supplied labor for mailing copies of the Visher-Indiana Scientists to members and took charge of sales. In addition to the distribution to institutions on the exchange list, the volume was forwarded to many other Indiana public, college and special libraries and to the Indiana high schools. Complimentary copies were mailed, too, to some of the major libraries outside the state and to members of the boards of the Indiana state supported colleges and universities. Perhaps this list should be expanded to include the trustees of the non-state supported institutions of higher learning. About 1,400 copies of the book remain. Four thousand forty-one copies were printed of which 341 were delivered to Dr. Visher, 3,700 to the Indiana State Library.

Press Secretary. Ben Moulton reported that publicity releases had been made concerning the spring meeting.

Program Committee. A. H. Meyer said that plans were well under way for the fall meeting of 1952.

Junior Academy of Science. In the absence of the Chairman, Prof. Lefler, Dr. Edwards reported that the Science Talent Search for 1951-52 was a fine success.

Membership Committee. A. A. Lindsey reported that 13 applications for membership including 1 Junior Academy had been received.

Old Business.

1. Upon the application from Dr. Rolla Ramsey, it was moved and approved that he become Member Emeritus and receive the Proceedings of the Indiana Academy of Science gratis.

2. Constitution Revision Committee. After a discussion on the question of types of membership, it was suggested that a written report be made at the fall meeting.

New Business.

1. P. D. Edwards reported that Dr. Arnim Hummel would replace C. M. Zieman as chairman of the Physics Section.

2. It was suggested that the secretary send a telegram containing best wishes to Mr. Charles C. Deam who could not attend the meeting.

All reports were accepted. The meeting adjourned at 5:45 P. M.

Dinner Meeting. Following the dinner in the Pavilion, President Edwards called the short business session to order in the Hotel.

1. The applications for membership were approved.

2. The rank of Emeritus membership was approved for Dr. Rolla Ramsey.

3. Dr. T. G. Yuncker on behalf of the Academy members thanked the Dunes Park and hotel staffs for their hospitality and the Program Committee for its efforts.

Following the business session, excellent illustrated talks were given by Drs. A. H. Meyer, Valparaiso University, and G. E. Olmstead, University of Chicago. Mr. T. P. Amidei showed a film in color of the dunes plant life.

The following morning, hikes were made by members of the Academy, They were led by J. B. Cope, M. A. Forsyth, F. R. Elliott, T. P. Amidei, R. C. Friesner, R. J. Kuster, J. H. Strietelmeier.

One hundred and sixty-seven names were inscribed on the roll of this meeting.

W. A. DAILY,
Secretary.

MINUTES OF THE EXECUTIVE COMMITTEE

VALPARAISO UNIVERSITY, OCT. 16, 1952

The Executive Committee of the 68th session was called to order by Pres. Edwards in Room 15, Kroencke Hall at 7:40 P.M. The minutes of the Spring Meeting, held at Dunes State Park, were read and approved. The reports of officers and committee representatives were presented and accepted as follows:

Academy Trustees. In the absence of Chairman Harger, the secretary reported as follows for the year 1951-52:

Assets as of Oct. 1, 1952	
Total at par or cost	$12,406.00
Cash Balance at the Indiana National Bank	840.98

Treasurer. Frank Welcher presented a tentative report for the period from January 1, 1952, to October 15, 1952.

A tentative report for 1951 was published in Vol. 61; so a final report approved by the Auditing Committee at the end of that year follows:

Receipts

Balance on hand January 1, 1951	$1,347.54	
Dues and initiation fees	1,895.00	
A.A.A.S. refund for research grants	175.00	
Designated gifts	8,125.00	
Authors' reprints Vol. 55	18.48	
Authors' reprints Vol. 57	65.65	
Authors' reprints Vol. 59	292.27	
Authors' reprints Vol. 60	590.66	
Publications sold by librarian	36.39	
		$12,545.99

Disbursements

1—Editor Vol. 60	$200.00
2—Expenses of Treasurer	100.09
3—Expenses of Secretary	120.89
4—Stationery	130.00
5—Preparation of the manuscript of Indiana Scientists under the direction of S. S. Visher	533.28
6—Program Committee	237.42
7—Duane Roller Research Grant	37.50
8—Winona Welch Research Grant	25.00
9—Kenneth Wagner Research Grant	75.00
10—Furniture for Indiana Academy of Science Library	410.65
11—Purchase of publications for Indiana Academy of Science Library	85.33
12—Binding, Indiana Academy of Science Library	299.68
13—Flowers for John S. Wright	15.00
14—Author Award 1951, S. S. Visher	25.00
15—Author Award 1951, Winona Welch	25.00

16—Authors' reprints Vol. 60	781.42		
17—Junior Academy Expenses	20.81		
18—Publication and distribution of Indiana Scientists	6,149.26		
19—Expenses to five officers as directed by action of 1947 Executive Committee	100.00		
20—Returned checks	4.00		
		$9,375.33	
*Balance on hand		3,170.66	
			$12,545.99

*Balance includes the following: $61.30 designated for use in the preparation of the manuscript for Indiana Scientists; $1,315.74 designated for use in the publication and distribution of Indiana Scientists; $14.35 designated for use in purchasing furniture for Indiana Academy of Science Library.

(Signed) FRANK WELCHER, Treasurer

(Signed) KARL S. MEANS,
S. E. ELLIOTT, Auditors

A final report for the period January 1, 1952, to December 31, 1952, approved by the Auditing Committee at the end of the year follows:

Receipts

Balance on hand January 1, 1952	$3,170.66	
A.A.A.S. refund on research grants	300.00	
Dues and initiation fees	2,032.00	
Designated gift	50.00	
Publications sold	74.30	
Extra pages in Proceedings, Vol. 61, Mrs. Clyde Malott	260.00	
Refund Program Committee expenses	4.04	
Author's reprints Vol. 59	70.89	
Author's reprints Vol. 60	137.48	
Author's reprints Vol. 61	439.25	
		$6,538.62

Disbursements

1—Editor Vol. 61	$200.00
2—Expenses of Secretary	146.04
3—Expenses of Treasurer	92.58
4—Expenses of President	4.30
5—Mailing Proceedings	76.18
6—Postage Indiana Scientists	180.21
7—Stationery	118.25
8—Authors' reprints Vol. 61	597.10
9—Junior Academy expenses	12.43
10—Binding, Indiana Academy of Science Library	500.99
11—Frank Welcher research grant	50.00
12—Lois I. Farquarson research grant	50.00
13—Benjamin Moulton research grant	50.00
14—Winona Welch research grant	25.00
15—Publications for library	48.16
16—Flowers, Dr. Friesner	15.00
17—Furniture, Indiana Academy of Science Library	88.65
18—Program Committee	344.81
19—Expenses to five officers as directed by action of 1947 Executive Committee	100.00

20—Prize award in Chemistry, Dr. Milton Burton	25.00		
21—Prize in Zoology, Dr. Theodore Torrey	25.00		
22—Academy conference A.A.A.S. expenses	5.00		
23—Returned checks	13.35		
		$2,768.05	
*Balance on hand, Jan. 1, 1953		3,770.57	
			$6,538.62

*Balance includes $61.30 remaining in treasury from preparation of manuscript for Indiana Scientists and $1,135.53 from publication and distribution of Indiana Scientists.

(Signed) FRANK WELCHER, Treasurer

(Signed) W. P. MORGAN,
S. E. ELLIOTT, Auditors

Auditing Committee. The auditor's report will appear in Vol. 62 of the Proceedings of the Indiana Academy of Science.

Bonding Committee. Dr. Ray C. Friesner, Chairman, reported that the bond covering the treasurer and the trustees is in good order. The next expiration date is November 18, 1953.

Research Grant. In the absence of Chairman Yuncker, Dr. Weatherwax reported that Dr. Winona Welch has now collected bryophytes in all of the 92 counties in Indiana, and completed determinations of the mosses. Dr. K. A. Wagner continues his studies of the Hepaticae or liverworts of Indiana. No new requests have been made for grants-in-aid from the Academy Research Fund. There is some money available for such grants in the fund.

Editor and Publication of Proceedings. Dr. A. A. Lindsey reported that the regular text comprising 307 pages was followed by an appendix including the complete membership list of the Academy. A red cloth cover was used to indicate the inclusion of the cumulative index, compiled by R. C. Friesner, which covered volumes 51-60.

Press Secretary. Ben Moulton wishes to thank Mr. Mel Doering of the Public Relations Office of Valparaiso University and Mr. John Barnett and Mr. Jack Shackelford of Butler University for their help and kindness in preparing and distributing the press releases. Press releases were made through the usual channels including radio and television.

Program. Dr. A. H. Meyer reported completed arrangements for the Fall Meeting. The attendance at the Spring Meeting was good and the number of papers to be given at the Fall Meeting compares very favorably with the past years.

Biological Survey. In the absence of Chairman Dr. C. B. Heiser, Jr., Dr. Edwards read portions of a letter from the chairman outlining possible future aims of the committee. No committee report was given.

Index. Dr. Ray C. Friesner reported as follows: "The cumulative index for volumes 51-60 of the Proceedings has been published as pages 357-455 of volume 61. Publication of this index has been made possible by funds from the Lilly Foundation. Indexing of volume 61, toward a cumulative index for volumes 61-70, is under way."

Indiana Science Talent Search. Chairman R. W. Lefler reported the following: College recognition of winners and participants in the Indiana Science Talent Search continues strong. Fifty-seven of the sixty-one participants of last year are in college. Forty-three have received scholarships ranging from Honorary to stipends covering full subsistence. No Indiana high school senior with real potential in science or engineering need be deprived of a college education because of financial conditions, if he will but prove his metal in the Science Talent Search, and maintain adequate scholastic standing once he is admitted to undergraduate study. The Indianapolis Times continues to provide the financial support which makes this activity of the Junior and Senior Academy possible. It was suggested that the secretary write a letter to Walter Leckrone, editor of the Indianapolis Times, thanking him for his continued loyal support of the Junior Academy.

Junior Academy. Dr. Michaud stated that there are at present thirty-eight clubs in the Junior Academy. The response to participation in this year's program has been unusually good. The Junior Academy has continued its affiliation with Science Clubs of America and cooperated in the 1952 state and national Science Talent Search. (Sixty-one students finished the requirements for the Science Talent Search and were invited to participate in the fifth annual Junior Scientists Assembly at the Claypool Hotel in Indianapolis last March.) The Indianapolis Times and the State Science Talent Search Committee, under the direction of Prof. R. W. Lefler, Purdue University, are to be highly commended for the splendid work being done in the identification of science talented youth.

Library. Miss Nellie Coats reported that from its expanding list of exchange agencies, the library is receiving forty new serial titles and has been able to fill in certain files by gifts from others, notably the Annals of the Museum of the Belgian Congo. Among new titles: Blyttia, published by the Norsk Botanisk Forening; Technical papers of the Australian Scientific and Industrial Research Organization, Division of Fisheries; the Boletim paulista de geografia; Memorias, Sociedade broteriana, Coimbra, Portugal; Pratika, Hellenikon hydrobiologikon institut; Annals, Ukranian Academy of Arts and Sciences, and several titles from the Slovene Academy of Sciences and Arts, Ljubljana.

Early volumes of the Philippine journal of science were obtained at a cost of $45.

A sum of $500 had been allotted for binding. One hundred sixty-three volumes were bound at a cost of $500.99.

The Library will very shortly mail copies of volume 61 to agencies on its exchange list. Members' copies were mailed by the Bookwalter printing establishment.

Representing the State Library and the Academy Library, your committee chairman attended the Special Libraries Association meeting in New York City last May.

Checking was completed of titles to be recorded in the Union List of Serials supplement to be issued by the H. W. Wilson Company.

Copies of the Index, volumes 1-50, and of Visher, Indiana Scientists are still available.

Membership. Dr. R. E. Girton reported that 47 applications for membership had been received to date. This makes a total of 62 to date for 1952.

Representative on Council of the A.A.A.S. Dr. W. H. Johnson stated that he attended the meetings held in Philadelphia on December 27 and 29, 1951. Nothing of immediate importance was noted insofar as our Academy was concerned.

Relation of Academy to State. Chairman Frank N. Wallace reported that the Academy should request $3,500 from the state to publish Vol. 62 of the Proceedings.

Nomination Committee. Chairman Paul Weatherwax recommended that Dr. R. N. Harger succeed himself as Chairman of the Academy Foundation Committee.

Dr. Ray C. Friesner, Chairman, and Scott McCoy continue on the Bonding of Trustees Committee.

Dr. W. H. Johnson to continue serving on the Research Grants Committee.

The following were recommended for the rank of fellow:

Charles L. Bieber, Geology, DePauw University
W. R. Breneman, Zoology, Indiana University
S. E. Elliott, Physics, Butler University
Geo. E. Gould, Entomology, Purdue University
H. H. Remmers, Psychology, Purdue University
Robt. R. Shrock, Geology, M. I. T.
Alvin Strickler, Chemistry, Evansville College
T. W. Torrey, Zoology, Indiana University

Old Business.

Constitution Revision Committee. Chairman W. A. Daily read the following proposed amendments to the constitution: Article II, Section 1. Members of this Academy shall be Annual members, Life members, Emeritus members and Fellows. Article II, Section 3. Members who are actually engaged in scientific work, who have recognized standing in their respective fields and who have been members of the Academy at least three years, may be recommended for nomination for election as Fellows by the Fellows Committee.

Nominations for Fellows shall be made to the chairman of the Fellows Committee previous to the annual meeting of the Executive Committee. The Fellows Committee shall submit its recommendations to the Executive Committee, which shall then pass its nominations on to the general session of the Academy for vote. A three-fourths vote of the members present shall elect. By-laws, Article II, Section (m). Fellows. The committee on Fellows shall be composed of one Fellow to be appointed by the President from each section of the Academy. The membership shall rotate alphabetically by section. Members from two sections shall be replaced each year except every fifth year when three members shall be replaced. Members of the initial committee shall serve one to five years depending upon the system of rotation. All appointments thereafter shall be for five years. A chairman shall be appointed annually by the President from the members of the committee for one year only.

These were so moved and approved.

John S. Wright Memorial Committee. Chairman W. E. Edington reported as follows: The Academy Library located in the State Library in Indianapolis be hereafter designated and referred to as the John Shepard Wright Memorial Library of the Indiana Academy of Science, and that a bronze plaque so inscribed be placed at a suitable point in the State Library. This was approved.

New Business.

1. Dr. R. W. Lefler presented the following resolution which was approved:

Be it resolved that the Indiana Academy of Science will support the movement of Science Fairs in the state of Indiana so as to bring about a better understanding of scientific endeavor on the part of the students and the teachers in the secondary schools and to make it possible to understand scientific experimentation and its application to the problems of modern living.

The Academy also welcomes the participation of the local talent in the National Science Fair and will support the movement so as to make it possible that this participation will be commensurable with the scientific effort of the State of Indiana.

2. A joint Spring Meeting of the Kentucky and Indiana Academies of Science was considered. Incoming officers and the Chairman of the Program Committee will consider such a move.

3. It was suggested and approved that Dr. Ray C. Friesner send a telegraph message to Dr. and Mrs. Charles C. Deam, who could not attend the Fall Meeting.

The meeting adjourned at 10:10 P. M. Refreshments were served during a reception for Academy members and guests in the Auditorium of Kroencke Hall.

MINUTES OF THE GENERAL SESSION

Valparaiso University, Oct. 17, 1952

Dean Walter E. Bauer of Valparaiso University welcomed the Academy to their campus. A response was given by President P. D. Edwards.

The minutes of the Executive Committee were read, corrected and approved.

W. E. Edington presented a short biography of the members who had died during the year. These were F. E. Bibbins, Charles Hire, E. G. Mahin, A. P. Poorman, H. W. Rhodehamel, E. R. Smith and J. E. Switzer.

Mr. Walter Blucher, Executive Director, American Institute of Planning Officials gave a very interesting talk on "Planning as a Science."

Dr. Harry G. Day, Chairman, Chemistry Department, Indiana University, talked on the subject, "Perspectives in the Science of Nutrition."

The meeting adjourned at 10:30 A. M. to meet in the various sections.

Luncheon was served in the University Cafeteria at 12:00 noon.

The annual dinner was held in the University Gymnasium. The Valparaiso University Orchestra and Choir presented several selections.

Dr. H. M. Powell, Vice-President of the Academy, introduced the 1952 officers. Dean W. E. Bauer, in the absence of President O. P. Kretzmann, presented greetings to the Academy members and guests.

Dr. P. D. Edwards then gave a scholarly presidential address on the subject, "The Role of Mathematics in Science." During the following short business session, Dr. R. E. Girton presented 59 applications for membership. The President instructed the Secretary to cast a unanimous ballot in favor of the applicants.

Dr. R. L. Shelley presented the following resolutions:

Resolved:

That this assembly wishes to thank Valparaiso University, its President, Dr. O. P. Kretzmann, Dean Walter E. Bauer and other officials for the fine manner in which they have entertained the Academy; for making its facilities available, doubtless at some cost to its student body; for the excellent food served us during our visit on their campus; for the science students who served to keep us well informed as to the progress of the individual sections; and otherwise to help and guide us about their campus; for Dr. A. H. Meyer and the able members of his Program Committee for the efficient manner in which they made and carried out the arrangements for this smooth running program. Recognizing the value of the efforts of all these workers in Valparaiso University to this Academy we hereby commend them for their efforts.

Resolved:

That the officers of this Academy have carried on our affairs during the past year with consummate skill and effectiveness and are due our deep appreciation. Our thanks also to the men of science who worked diligently as Divisional Chairmen, developing outstanding programs in each of the 12 sections. Our thanks also to all those who presented papers without whose endeavors this meeting could not have been successful.

In the absence of John S. Karling, President Edwards reported that the Invitations Committee had accepted the offer to hold the 1953 Fall Meeting on the Earlham College campus.

Editor A. A. Lindsey announced the selection by the Awards Committee of the following papers for prizes:

The David Starr Jordan Prize in Zoology is awarded to Dr. Theodore W. Torrey for his paper, "Balanoglossus and the Origin of the Vertebrate Nephros." The William A. Noyes Prize in Chemistry is awarded to Dr. Milton Burton for his paper "Some Elementary Physical and Chemical Processes in Radiobiology."

The Nominations Committee report was given by the Chairman, Dr. Paul Weatherwax. Divisional Chairmen for 1953 will be: Anthropology, Paul Gebhard, Indiana University; Bacteriology, R. L. Thompson, Indiana University Medical Center; Botany, Daniel Den Uyl, Purdue University; Chemistry, J. H. Billman, Indiana University; Entomology, M. Curtis Wilson, Purdue University; Geology and Geography, Clifford Adams, Hanover College; History of Science, C. L. Porter, Purdue University; Mathematics, Arthur Rosenthal, Purdue; Physics, R. E. Winn, Indiana State Teachers College; Psychology, (to be announced); Zoology, W. H. Johnson, Wabash College.

The following persons were recommended to serve as the 1952 officers: President, H. W. Powell, Eli Lilly and Company; Vice-President, A. H. Meyer, Valparaiso University; Secretary, W. A. Daily, Eli Lilly and Company; Treasurer, Frank Welcher, Indiana University Adult Education Center, Indianapolis; Editor, Ben Moulton, Butler University; Press Secretary, J. A. Clark, Department of Conservation, Indianapolis.

The sixty-eighth annual meeting of the Indiana Academy of Science with a general attendance of 395 and a dinner attendance of 125, was adjourned.

W. A. DAILY, Secretary

CONSTITUTION OF THE INDIANA ACADEMY OF SCIENCE[1]

ARTICLE I.

Section 1. This Association shall be called the Indiana Academy of Science.

Sec. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science. The Academy shall promote intercourse between men engaged in scientific work, especially in Indiana, assist by investigation and discussion in developing and making known the educational, material and other resources and riches of the state, prepare for publication such reports of investigation and discussion as may further the aims and objects of the Academy as set forth in these articles.

Since the state has agreed to make an annual appropriation to assist the publication of such proceedings, the Academy shall upon the request of the governor, or one of the several departments of the state, through the governor, act through its Executive Committee, or Subsidiary Committee as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the state; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy, in so far as published by the state, shall become a public document and be circulated by the Indiana State Library as agreed upon by the Library and the Academy Committee on Relation of the Academy to the State.

ARTICLE II.

Section 1. Members of this Academy shall be Annual members, Life members, Emeritus members and Fellows.

Sec. 2. Any person interested in any department of scientific work shall be eligible to membership. Annual members may be elected at any meeting of the Academy. New members shall pay an initiation fee of one dollar and the annual dues for one year. Any person who shall contribute twenty-five times the annual dues to the funds of this Academy may be elected a Life member of the Academy, free of assessment. Applications for membership shall be referred to a Membership Committee which shall report to the Academy before the election.

Sec. 3. Members who are actually engaged in scientific work, who have recognized standing in their respective fields and who have been members of the Academy at least three years, may be recommended for nomination for election as Fellows by the Fellows Committee.

Nominations for Fellows shall be made to the chairman of the Fellows Committee previous to the annual meeting of the Executive Committee.

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[1] As revised, October 17, 1952.

The Fellows Committee shall submit its recommendations to the Executive Committee, which shall then pass its nominations on to the general session of the Academy for vote. A three-fourths vote of the members present shall elect.

Sec. 4. The Indiana Academy of Science shall actively promote the organization and operation of local science clubs in connection with secondary schools of the state. Such of these clubs as elect to become members shall constitute the Indiana Junior Academy of Science.

The President shall appoint annually a committee of five members from the Indiana Academy of Science to have full charge, within the Academy, of the Junior Academy of Science. It shall formulate the requirements for membership of local science clubs, and election of such clubs must be approved by the Executive Committee of the Academy.

Each applicant club, upon meeting Academy affiliation requirements, payment of an entry fee of $1.00 and an affiliation fee equal to the annual dues of annual members, and upon recommendation of the committee in charge, shall receive for its files a certification of membership signed by the President, Secretary, and Treasurer of the Academy. Such affiliation shall continue upon payment of annual affiliation fee so long as the club continues to meet requirements of membership. Each affiliated club will receive one copy of the Proceedings of the Indiana Academy of Science.

The Committee, in council with the President, Secretary and Treasurer, shall formulate a program of work. An annual report of the progress made shall be presented to the Executive Committee of the Indiana Academy of Science by the chairman of the Academy Committee on Junior Academy of Science.

Sec. 5. Any member of the Academy because of age or condition of health may, upon recommendation of the Secretary and approval of the Executive Committee by a three-fourths vote of the members present, become an Emeritus member. Emeritus members shall pay no further dues but shall be entitled to all privileges of Academy membership except receipt of the Proceedings, unless by special act of the Executive Committee, in recognition of outstanding services to the Academy, the Proceedings shall be ordered continued to such Emeritus members.

ARTICLE III.

Section 1. The officers of the Academy shall be elected at the annual meeting and shall hold office for the calendar year following their election. They shall consist of a President, Vice-President, Divisional Chairmen, Secretary, Press Secretary, Editor, and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-presidents of the Academy and chairmen of all standing committees, shall constitute the Executive Committee. The Divisional Chairmen shall be chosen by ballot by their respective sections during the annual meeting. Each Divisional Chairman shall have the power to appoint an Assistant Chairman to assist him in the sectional duties. No section shall have representation on the Executive Committee without the sanction of the Executive Committee.

Sec. 2. The annual meeting of the Academy shall be held at a time and place designated each year by the Executive Committee. There shall also be a spring or summer field meeting at such time and place as may be decided upon by the Executive Committee or Subsidiary Committee. Other meetings shall be called at the discretion of the Executive Committee. The officers of the Academy shall constitute the Council of the Academy and represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

Sec. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS

ARTICLE I.

Section 1. President: The President shall preside over all meetings of the Academy, of the Executive Committee, and of the Council. He shall be responsible for the administration of all laws and regulations of the Academy and of its committees. He shall call special meetings of the Academy, of the Executive Committee or of the Council whenever he shall consider such meetings necessary, or upon the request of the Executive Committee. He shall appoint all standing committees.

Sec. 2. Vice-President: In the absence of the President, the Vice-President shall preside over all meetings as specified in Section 1 of this article, and he shall assume the powers and prerogatives of the President, in so far as the circumstances shall warrant.

Sec. 3. Divisional Chairmen: The Divisional Chairmen shall preside over the meetings of their sections. They may each appoint an assistant chairman to assist in the work of the section and to preside in their absence.

Sec. 4. Secretary: The Secretary of the Academy shall be secretary also of the Executive Committee and of the Council. He shall keep a permanent record of all proceedings of these bodies, including all resolutions and formal actions. He shall issue, or cause to be issued, all notices of meetings. He shall maintain a register of the members of the Academy.

Sec. 5. Press Secretary: It shall be the duty of the Press Secretary to furnish the press with notices of meetings of the Academy and with such other material as may be suitable for purposes of publicity, to the general end that the public may be acquainted with the purposes and with the work of the Academy.

Sec. 6. Editor: The Editor, with the assistance of such members or committees as shall be designated by the Academy for the purpose, shall have charge of the publication and distribution of the Proceedings of the Academy, and any other special publications, not directly entrusted to other officers, individuals, or committees. He shall prepare and submit to the Executive Committee reports covering his receipts and expenditures in connection with these duties.

Sec. 7. Treasurer: The Treasurer shall have the custody of all funds of the Academy, except such as shall have been, by specific action of the Academy, entrusted to other officers or committees. He shall issue bills for dues and assessments payable and he shall make proper receipt for the same. All bills properly chargeable to the Academy shall be paid by check of the Treasurer, but only after approval by the President and the Secretary of the Academy. He shall prepare complete reports of Academy finances for submission at the annual meeting, and at such other times as may be directed by the Academy or by the Executive Committee.

ARTICLE II.

Section 1. Standing Committees: The following standing committees shall be appointed by the President of the Academy, to serve for one year unless reappointed or stated otherwise:

(a) The Academy Representative on the Council of the American Association for the Advancement of Science shall represent the Academy in all matters coming before that Council.

(b) Archeological Survey. This committee shall have charge of all matters of archeological and historical nature.

(c) Auditing. This committee shall audit the books of the Treasurer, and of such other officers or committees as shall have been given custody of the funds of the Academy. It shall report the results of such audit at the annual meeting of the Academy.

(d) Biological. This committee shall have charge of all matters pertaining to the distribution of the fauna and flora of the state.

(e) Junior Academy of Science. This committee shall have charge of all matters pertaining to the relations between the Academy and the chapters of the Junior Academy of Science.

(f) Library. This committee shall have charge of all matters pertaining to the library of the Academy and its relation to the State Library.

(g) Membership. This committee shall receive applications for membership in the Academy and it shall submit reports and recommendations covering such applications, at any regular meeting of the Academy.

(h) Nominations. This committee shall consider and report to the annual meeting, nominations for President, Vice-President, Secretary, Press Secretary, Treasurer and Editor. Nominations may be supplemented by nominations from the floor.

(i) Program. The Program Committee shall make all arrangements for the regular or special meetings of the Academy.

(j) Publication of Proceedings. This committee shall assist the Editor in matters pertaining to publication and distribution of the Proceedings.

(k) Relation of Academy to State. This committee shall have charge of all relations between the Academy and the state government.

(l) Research. This committee shall consider and report to the Academy concerning all policies that are proposed for the encouragement and promotion of scientific research within the state.

(m) Fellows. The committee on Fellows shall be composed of one Fellow to be appointed by the President from each section of the Academy. The membership shall rotate alphabetically by section. Members from two sections shall be replaced each year except every fifth year when three members shall be replaced. Members of the initial committee shall serve one to five years depending upon the system of rotation. All appointments thereafter shall be for five years. A chairman shall be appointed annually by the President from the members of the committee for one year only.

Sec. 2. Announcement of Committee Membership: The membership of all standing committees shall be announced by the President within a reasonable time after their appointment and such membership shall be published in the Proceedings of the Academy: *Provided, however*, That at his discretion the President may withhold the announcement of the membership of the Committee on Nominations until this committee is ready to report at the annual meeting.

Sec. 3. The President shall be, ex officio, a member of all standing committees.

Sec. 4. All committees shall be subject to the call of their respective chairmen.

Sec. 5. Special Committees: Special committees may be appointed by the President, or in any other manner that may be specified by the Academy or by the Executive Committee.

ARTICLE III.

Section 1. These by-laws may be amended at any regular or special meeting of the Academy.

ARTICLE IV.

Section 1. Twenty-five or more members of the Academy shall constitute a quorum for the transaction of business.

Sec. 2. One-fourth or more of the members of the Executive Committee or of the Council shall constitute a quorum respectively for these two bodies.

ARTICLE V.

Section 1. Members whose dues remain unpaid for two years, having been annually notified of their arrearages by the Treasurer, shall have their names stricken from the roll.

Sec. 2. The annual dues shall be determined by the Executive Committee.

ARTICLE VI.

Section 1. The rules of procedure prescribed by Roberts' Rules of Order shall govern all business meetings of the Academy and of the Executive Committee.

EDITORIAL POLICY

PART I.

Since the Proceedings is the annual exhibit of the Indiana Academy of Science, members should not jeopardize their reputation or that of the Academy by submitting and anticipating publication of inferior papers. On the other hand, the Academy, with an aim to encourage and assist younger scientists, should be lenient and assist the inexperienced workers as long as the content of papers is reliable and worthy and a contribution to knowledge. The experienced workers should feel a responsibility for all papers from the younger men. The opportunity presented by the

Academy as an outlet for research in a small way constitutes a service to science and to the state.

The Editorial Board or Committee should consist of the Editor as chairman and two other members, at least one of whom should be a past editor. This board or committee may designate one member in each major science of the Academy to judge and edit papers in their field. The Editor may request the opinion of out-of-state scientists but the Editorial Board has final authority. It is suggested that the Editor and Editorial Board formulate a revised Editorial Code for the guidance of writers.

PART II.

In selecting papers for publication in the Proceedings of the Indiana Academy of Science the following principles shall act as a guide for the Editor and/or Editorial Committee.

1. Papers by resident members of the Academy will be given preference, other things being equal, and the Editor or Editorial Committee shall refuse papers by non-members, and members who are in arrears.

2. Papers on the printed program will have publication priority, if they meet other publication requirements.

3. Papers relating to Indiana flora, fauna, ecology, geography and geology will have preference over similar papers dealing with flora, fauna, etc., of regions outside Indiana.

4. Papers submitted for publication should be only those which have not been published elsewhere or will not be submitted for publication elsewhere.

5. Other things being equal, only one paper by the same author may be accepted by the Editor if funds do not permit the publication of all suitable papers submitted for publication. Authors submitting more than one paper should indicate the paper to be given preference.

6. The Editor and Editorial Committee shall have the privilege of using referees wherever they deem it advisable, the action of the Editorial Committee to be final.

7. Each paper should be a contribution to knowledge. Briefness and clarity should be the rule in writing.

8. Illustrations and tables should be used only when necessary and/or when they add materially to the paper.

9. Other things being equal, papers should be selected on the basis of merit.

NEW MEMBERS 1952[1]

Angrick, Warren Lewis, 5141 N. Illinois St., Indianapolis, Ind.	Bo, Z
Barrett, John P., Armour & Co., Research Div., Union Stock Yards, Chicago 9, Ill.	E
Beckett, K. Eileen, 508 N. Lebanon St., Lebanon, Ind.	Bo
Blair, Walter Beale, Dept. of Geography, Butler Univ., Indianapolis 7, Ind.	G
Bracken, Lawson E., 730 E. Washington St., Indianapolis, Ind.	G
Brake, Earl F., Butler Univ. Col. of Pharmacy, Indianapolis 7, Ind.	C
Bruson, Ruth, 6307 N. Navajo Ave., Chicago 30, Ill.	Bo
Burdick, Dr. Allan B., Dept. of Biological Sciences, Purdue Univ., Lafayette, Ind.	Bo
Carter, Gordon, R. R. 1, Gaston, Ind.	Bo
Cassady, Donald R., 6916 Park Ave., Indianapolis, Ind.	C
Christens, John M., Dept. of Chemistry, Indiana Univ., Bloomington, Ind.	C
Clark, Dr. William C., Dept. of Biochemistry and Pharmacology, Indiana Univ. School of Medicine, Indianapolis 7, Ind.	Z
Coleman, Robert M., Box 126, Dept. of Biology, Univ. of Notre Dame, Notre Dame, Ind.	Z
Crowder, Dr. Harold W., 4026 Avondale, Fort Wayne, Ind.	Z
Dale, Mrs. Catherine W., 222 N. Harvey Ave., Griffith, Ind.	Bo
Davis, Jeanette M., 3204 E. 39th St., No. 551, Indianapolis, Ind.	Ba
Davis, Dr. Ralph L., No. 3 David Ross Rd., W. Lafayette, Ind.	Bo
De Vol, Prof. Lentz C., Valparaiso Univ., Valparaiso, Ind.	Ph
Dewar, Norman E., 330 W. Fowler St., W. Lafayette, Ind.	Ba
Dufford, Prof. R. T., Dept. of Physics, Evansville Col., Evansville, Ind.	Ph
Downie, Dr. N. M., 1621 Purdue Street, Lafayette, Ind.	Ps
Farquharson, Lois, Dept. of Botany, Indiana Univ., Bloomington, Ind.	Bo
Fisher, Dr. Dale J., Oak Ridge National Lab., P. O. Box P, Oak Ridge, Tenn.	C
Fisher, T. Richard, Dept. of Botany, Indiana Univ., Bloomington, Ind.	Bo
Ford, Dr. Lee, Anderson Col., Anderson, Ind.	Bo
Gebhard, Dr. Paul H., Wiley Hall, Ind. University, Bloomington, Ind.	A
Graebner, Dr. Oliver E., Valparaiso Univ., Valparaiso, Ind.	Ps
Grula, Ed. A., FPHA 333-1, W. Lafayette, Ind.	Ba
Hamilton, Donald W., U. S. Bur. Ent. & Pl. Quar., 1237 Wash. Ave., Vincennes, Ind.	Ent
Harned, Dr. B. K., Mead-Johnson Research Labs., Evansville 21, Ind.	C
Hart, John Robert, R. R. 1, Princeton, Ind.	Bo
Hudson, John T., City Schools, Falls City, Nebr.	G
Hueber, Francis M., 1603 Central Ave., Apt. 115, Indianapolis 4, Ind.	G
Hull, Dr. Robert N., 2301 Elizabeth St., Indianapolis, Ind.	Ba, Bo, Z
Humphrey, William F., 202 E. 33rd St., Indianapolis 5, Ind.	Bo

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[1] Abbreviations following the members' listings indicate the section of the Academy with which they are affiliated. In addition to the usual abbreviations is E, Entomology.

Jackson, Raymond C., 612 S. Fess Ave., Bloomington, Ind.	Bo
Kavanagh, Dr. Virgene, V. Kavanagh Lab., 812 South 25th St., Terre Haute, Ind.	Z, Ba
Kline, Doris Ruth, Rogers Center, Box 71, Bloomington, Ind.	Z
Knight, Percy Leonard, 1626 N. Ironwood Dr., South Bend, Ind.	Z
Koenig, Harold P., Valparaiso Univ., Valparaiso, Ind.	C
Lawrence, John L., Wabash Col., Crawfordsville, Ind.	M
Le Zotte, Lloyd A., Jr., Dept. of Biological Sciences, Purdue Univ., Lafayette, Ind.	Z
Ling, Dr. Rufus C., 898 E. Jefferson St., Franklin, Ind.	Ph
Lipscomb, Robert G., 702 Bacon, Indianapolis, Ind.	Bo
Lockard, Dan H., J. I. Holcomb Research Labs., 4401 Cold Spring Rd., Indianapolis, Ind.	E
Lyman, Sally Jane, 5947 Crest View Dr., Indianapolis 20, Ind.	Bo
McCormick, Louise, 925 N. Hawthorne Lane, Indianapolis 19, Ind.	Bo, H
Macklin, Jerry M., 108 Waldron, W. Lafayette, Ind.	E
Maxwell, Thomas J., 1504 Main Ave., West, Massillon, Ohio	A
Meibohm, Dr. Alvin W., Valparaiso, Univ., Valparaiso, Ind.	C
Mitchell, Max L., 1330 W. Michigan St., Rm. 377, Indianapolis, Ind.	G, H
Monaco, Lawrence H., Box 126, Notre Dame Univ., Notre Dame, Ind.	Z
Muller, Dr. Joseph Charles, Dept. of Chemistry, Indiana Univ., Bloomington, Ind.	C
Newhouse, Florence M., 5864 Lowell Ave., Indianapolis, Ind.	Bo
Nielson, Blanche S., 1015 Crescent Ave., Fort Wayne 3, Ind.	G
Peckham, Richard S., Box 126, Dept. of Biology, Notre Dame Univ., Notre Dame, Ind.	Z
Phillips, Ralph W., 1121 W. Michigan St., Indianapolis, Ind.	C
Pounds, Norman J. G., Dept. of Geography, Indiana Univ., Bloomington, Ind.	G, H
Reed, Helen E., Apt. 1, 423 N. Lebanon St., Lebanon, Ind.	Bo, Z
Riedhart, Joseph M., Dept. of Biological Sciences, Purdue Univ., Lafayette, Ind.	Bo
Robinette, Chester W., 1111 Union St., Lafayette, Ind.	E
Romberg, Paul F., Wabash Col., Crawfordsville, Ind.	Bo
Rosauer, Elmer A., 116 Marstellar St., W. Lafayette, Ind.	G
Rothwell, Norman V., Dept. of Botany, Indiana Univ., Bloomington, Ind.	Bo
Shaver, Robert J., Box 126, Dept. of Biology, Notre Dame Univ., Notre Dame, Ind.	Z
Siebe, Mrs. Grace D., Dept. of Microbiology, Indiana Univ. Medical Center, 1040-1232 W. Michigan St., Indianapolis 7, Ind.	Ba
Smith, Lewis O., Jr., Valparaiso Univ., Valparaiso, Ind.	C
Stanley, Dr. Paul E., School of Aeronautics, Purdue Univ., Lafayette, Ind.	Ph
Stantz, Guy, Principal, Gerstmeyer Tech. H. S., Terre Haute, Ind.	A, Bo, G
Starcs, Karlis, 5870 Sunset Lane, Indianapolis 20, Ind.	Bo
Stewart, Lola, 341 McKinley St., Gary, Ind.	Bo, Z
Stoutamire, Warren P., Dept. of Botany, Indiana Univ., Bloomington, Ind.	Bo

Taylor, James Woodall, Dept. of Geography, Indiana Univ., Bloomington, Ind. G
Thompson, Dr. Randall L., Indiana Univ. Medical Center, Indianapolis 7, Ind. Ba
Throw, Prof. Francis E., Wabash Col., Crawfordsville, Ind. Ph
Townsend, Earl C., Jr., 23 Kenmore Rd., Indianapolis, Ind. A
Van Derbilt, Betty, 5131 Central Ave., Indianapolis, Ind. G
Wallace, Edith, 617 Buchanan St., Gary, Ind. Bo, Z
Weaver, Dr. R. H., Dept. of Bact., U. of Kentucky, Lexington, Ky. Ba
Wolfe, Ruby, 3267 College Ave., Indianapolis, Ind. Bo, Z
Wood, Raymond A., Box 126, Dept. of Biology, Univ. of Notre Dame, Notre Dame, Ind. Z
Young, Robert N., Dept. of Geography, Indiana Univ., Bloomington, Ind. G

JUNIOR ACADEMIES

Science Club, Calumet High School, 5815 W. Ridge Rd., Gary, Ind.
Biology Club of Tolleston School, 1700 Taney, Gary, Ind.
Science Club of Hobart, Ind., Hobart High School, Hobart, Ind.
Junior Izaak Walton League of John Adams High School, Cor. of Twyckenham and Mishawaka Ave., South Bend, Ind.

INDIANA JUNIOR ACADEMY OF SCIENCE OFFICERS FOR 1952
David Brenner, New Castle, Indiana, President.
Nancy Miller, Elkhart, Indiana, Secretary.

INDIANA JUNIOR ACADEMY OF SCIENCE

Officers for 1952:

President: David Brenner, Science Club, New Castle High School, New Castle.

Vice-President: Joyce Baldwin, Phy-Chem Club, Elmhurst High School, Fort Wayne.

Secretary: Nancy Miller, Junior Academy, Elkhart High School, Elkhart.

Press Secretary: David Taylor, Science Club, Thomas Carr Howe High School, Indianapolis.

Members of the Council: Evelyn Wagoner, Elkhart, (1948-1952); Max Forsyth, Indianapolis, (1949-1953); Harold Stewart, Bloomington, (1949-1954); Arthur L. Smith, South Bend, (1950-1955); Charles E. Karst, Mishawaka, (1952-1956).

PROGRAM OF THE TWENTIETH ANNUAL MEETING

October 18, 1952

University Auditorium

Valparaiso University, Valparaiso, Indiana

8:00-10:00 a.m. Exhibits, Science Building, Room 2.

10:00 a.m. Morning Session, University Auditorium.

General Session, David Brenner, presiding.

Reading of the minutes of the 1951 meeting, Nancy Miller, Secretary.

Greetings, Dr. Walter E. Bauer, Dean of the Faculty, Valparaiso University.

1. Herpetology as a Hobby. Helen Emmons and Don Lambdin, Junior Academy of Science, Elkhart High School, Elkhart.
2. Nuclear Energy in the Sun. (Chart talk.) David Nowicki, Central Junior Academy, Central High School, South Bend.
3. Ways of Living in Mexico. (Illustrated.) Mina Zaldivar, Biology Club, Lew Wallace High School, Gary.
4. Distillation of Crude Oil. Mike Deitch, Senior Science Club, State High School, Terre Haute.
5. How I Became Interested in Insects. Robert MacFarland, Biology Club, Tolleston High School, Gary.
6. Chemistry of Coal. Jim Griffiths, Senior Science Club, State High School, Terre Haute.
7. A Study of the Reptiles of St. Joseph County. (Illustrated.) Warren Schackenman, Central Junior Academy, Central High School, South Bend.
8. The Fluorescence of Minerals. Joe Mosier, National Scientific Honor Society, Bloomington High School, Bloomington.

12:00 Noon Luncheon.

1:30 p.m. Afternoon Session, University Auditorium.

Business Session.

9. Steps for Beginners in Bacteriology: Special Work in Immunology. John Costas, National Scientific Honor Society, Bloomington High School, Bloomington.
10. Meteorology and Weather. (Illustrated.) Richard Stevens, Science Club, Mishawaka High School, Mishawaka.
11. The Mighty Atom. Ruth McKnight, National Scientific Honor Society, Bloomington High School, Bloomington.
12. Effect of Vitamin A Deficiency in Hamsters. Sybil Johnson, Science Club, University High School, Bloomington.

MINUTES

The twentieth annual meeting of the Indiana Junior Academy of Science was held Saturday, October 18, 1952 in the University Auditorium of Valparaiso University, Valparaiso, Indiana.

The exhibit room opened at 8:00 a.m. in Room 2 of the Science building. Many interesting scientific projects and demonstrations were displayed by the club members.

The general session was called to order at 10:15 a.m. by President David Brenner, Science Club, New Castle High School, New Castle. The president introduced the state secretary, Nancy Miller, Junior Academy, Elkhart High School, Elkhart. The other state officers, Vice-President Joyce Baldwin, Phy-Chem Club, Elmhurst High School, Fort Wayne, and Press Secretary David Taylor, Science Club, Howe High School, Indianapolis, were unable to attend the meeting.

The minutes of the 1951 meeting were read by the secretary. Dr. Walter E. Bauer, Dean of the Faculty, Valparaiso University, welcomed guests and members of the Junior Academy. He spoke briefly on the progress in science and encouraged the young high school people to continue their interest in science.

Helen Emmons and Don Lambdin, Junior Academy, Elkhart High School, Elkhart, opened the morning program of student papers with a talk on "Herpetology as a Hobby." They discussed the various reptiles and showed a part of their collection of living animals to the audience.

"Nuclear Energy in the Sun," was the topic presented by David Nowicki, Central Junior Academy, Central High School, South Bend.

Mina Zaldivar, Biology Club, Lew Wallace High School, Gary, spoke on "Ways of Living in Mexico." Having lived in Mexico until recently, Mina gave a very interesting account of her experiences there. Her talk was illustrated with recent scenes of Mexico.

A talk on "Distillation of Crude Oil" was given by Mike Deitch, Senior Science Club, State High School, Terre Haute. The apparatus used in the distillation process was on display in the exhibit room in the science building.

Next, Robert MacFarland, Biology Club, Tolleston High School, Gary, discussed how he became interested in insects. He had his collection on display.

"Chemistry of Coal" was the topic presented by Jim Griffiths, Senior Science Club, State High School, Terre Haute.

Warren Schackenman, Central Junior Academy, Central High School, South Bend, discussed the subject "A Study of the Reptiles of St. Joseph County." The kodachrome slides that Warren used to illustrate his talk added considerable interest to the subject.

The last talk of the morning session was given by Joe Mosier, National Scientific Honor Society, Bloomington High School, Bloomington. In discussing "The Fluorescence of Minerals," he showed the different reaction of various minerals to fluorescent light.

The morning session was adjourned at 12:00 noon.

Luncheon was served in the University cafeteria. After lunch, students and guests explored the University campus and visited the exhibit room.

The afternoon session was called to order by David Brenner at 1:30 p.m. The first item of the business meeting was the election of new officers. A partial slate of officer candidates was submitted by the council and additional nominations were accepted from the floor. The following officers were elected for 1953: President, David Stevenson, Phy-Chem Club, Elmhurst High School, Fort Wayne; Vice-President, Don Lambdin, Junior Academy, Elkhart High School, Elkhart; Secretary, Mina Zaldivar, Biology Club, Lew Wallace High School, Gary; Press Secretary, Gail Diamondis, Junior Academy, Central High School, South Bend.

The first speaker of the afternoon session was Richard Stevens, Science Club, Mishawaka High School, Mishawaka, who presented an illustrated talk on "Meteorology and Weather."

Sybil Johnson, Science Club, University High School, Bloomington, spoke on "The Effect of Vitamin A Deficiency on Hamsters." Her talk attracted considerable attention because of the caged hamsters that were brought along as a part of the demonstration.

Ruth McKnight, National Scientific Honor Society, Bloomington High School, Bloomington, concluded the program of papers with a talk on "The Mighty Atom."

The president announced that Miss Edith Wallace, Sponsor, Biology Club, Tolleston High School, Gary, was elected new council member to succeed Miss Evelyn Wagoner of Elkhart whose term expired in 1952.

Professor Howard H. Michaud, Department of Forestry, Purdue University, and State Sponsor of the Junior Academy, reported on the progress of clubs during the past year. Professor Michaud called the roll of clubs and asked each to stand. Special mention was made of the new clubs for 1952 which included the following: Biology Club, Tolleston High School, Gary, Edith Wallace, Sponsor; Science Club, Hobart High School, Hobart, Lola Stewart, Sponsor; Science Club, Calumet Township High School, Gary, Mrs. Catherine Dale, Sponsor; Junior Walton League, John Adams High School, South Bend, Ernest Litweiler, Sponsor.

Professor Michaud announced that David Nowicki, Junior Academy, Central High School, South Bend, had been chosen to receive the annual title of "best boy." There were no candidates for the "best girl" award. The annual selections are made by the council. The choice of winners is based upon information on each student submitted by sponsors of science clubs. Recipients of this honor are given a year's membership in the American Association for the Advancement of Science.

Professor Ralph W. Lefler, Purdue University, was called upon to speak about the State Science Talent Search. Professor Lefler explained that the National Science Talent Search selects forty winners who are given a trip to Washington, D. C. From this group two national winners each receive a four year college scholarship of $2,800 and $2,000 respectively. Eight more winners receive $400 each and $3,000 additional in scholarships is awarded.

Last year Indiana had sixty-one entries who completed all of the requirements. Eight of the students received honorable mention and two were in the group of forty who went to Washington, D. C. The total in scholarship funds received by Indiana students who have been winners in the State Science Talent Search represents $29,600.

Thirty-nine high school science clubs are affiliated with the Indiana Junior Academy of Science. The number of active clubs has doubled in the past five years. It is believed that many other high schools of Indiana would benefit through participation in the work of the Junior Academy.

After expressing his thanks to those who took part in the program and to everyone who attended, President David Brenner adjourned the 1952 meeting.

Over two hundred club members, sponsors and guests registered for the meeting. It was the largest attendance the Junior Academy has enjoyed at an annual meeting.

EXHIBITS

Sun Spots; Living Reptiles: Junior Academy, Elkhart High School, Elkhart.

Telephone Switchboard: Science Club, Hobart High School, Hobart.

Noise Suppression in High Fidelity Reproduction; Tape Recorder; Oscilloscope; Blast Furnace for Production of Pig Iron: Phy-Chem Club, Elmhurst High School, Fort Wayne.

Insect Collections; Drying Boards for Insects; Leaf Collections: Biology Club, Lew Wallace High School, Gary.

Insect Collection: Biology Club, Tolleston High School, Gary.

Chemistry of Coal; Distillation of Crude Oil: Science Club, State High School, Terre Haute.

Common Rocks and Their Cycle: Science Club, New Castle High School, New Castle.

INDIANA JUNIOR ACADEMY OF SCIENCE CLUBS
FALL 1952

	Town	*School and Club*	*Sponsor*
1.	Anderson,	H. S., Science (1936)	B. B. Horton
2.	Attica	H. S., Sci.-Math. (1949)	J. Claude Daugherty
3.	Bedford	H. S., Science (1951)	Robert E. Carpenter
4.	Bloomington	H. S., Nat'l Scientific Honor Society (1931)	Harold Stewart
5.	Bloomington	University H. S., Jr. Academy (1938)	E. Wayne Gross P. L. Whitaker
6.	Clayton	H. S., Jr. Academy (1951)	Howard C. Lewis
7.	Crawfordsville	H. S., Up-N-Atom (1950)	David Wells
8.	Elkhart	H. S., Jr. Academy (1940)	Evelyn Wagoner
9.	Ft. Wayne	Central H. S., Nature (1940)	Iva Spangler
10.	Ft. Wayne	North Side H. S., Nature, (1936)	Vesta Thompson
11.	Ft. Wayne	Elmhurst H. S., Phy-Chem. (1935)	Ruth Wimmer
12.	Gary	Edison H. S., Beaker Breakers (1947)	Mrs. Martha B. Connor
13.	Gary	Lew Wallace H. S., Biology (1935)	Lola Lemon
14.	Gary	Lew Wallace H. S., Klub Kem (1941)	Mrs. Helen McKenzie
15.	Gary	Tolleston H. S., Biology (1952)	Edith Wallace

	Town	*School and Club*	*Sponsor*
16.	Gary	Tolleston H. S., Future Scientists of America (1949)	Juanita Joice
17.	Gary	Wirt H. S., Biology (1945)	Mrs. Frances Huddleston
18.	Gas City	H. S., Science (1936)	Roy McKee
19.	Hammond	Morton School, Science (1949)	Faye E. Moorman
20.	Hobart	H. S., Science (1952)	Lola Stewart
21.	Huntingburg	H. S., Science, (1949)	Wilmer K. Pellett
22.	Indianapolis	Shortridge H. S., Science (1931)	Henrietta A. Parker (Mrs.)
23.	Indianapolis	Shortridge H. S., Nature (1947)	Max Forsyth
24.	Indianapolis	Technical H. S., Nature (1932)	Howard L. Cook
25.	Indianapolis	Howe H. S., Science (1949)	Jerry Motley
26.	Indianapolis	Washington H. S., Science (1931)	Estil Van Dorn
27.	Lafayette	Centennial School, Science (1948)	
28.	Lowell	H. S., Science (1935)	Robert J. Brannock
29.	Marion	H. S., Science (1936)	Keith Stroup
30.	Mishawaka	H. S., Science (1936)	Darl F. Wood
31.	New Albany	H. S., Science (1935)	L. S. Rose
32.	New Castle	H. S., Science (1947)	Mary Rankin Garland Bookout
33.	Richmond	H. S., Science (1950)	Kathryn Coulter Elma Eliason
34.	South Bend	Central H. S., Jr. Izaak Walton & Chem. Club (1939)	A. L. Smith F. S. Sanford
35.	Sullivan	H. S., Camera (1939)	Ruth Hinkle
36.	Terre Haute	State H. S., Senior Science (1939)	Russell McDougal
37.	Valparaiso	H. S., Science (1931)	Gerald Doeden
38.	Gary	Calumet Twp. H. S. Science (1952)	Mrs. Catherine Dale
39.	South Bend	John Adams H. S., Jr. Izaak Walton (1952)	Ernest Litweiler

NECROLOGY

Will E. Edington, DePauw University

Francis Eugene Bibbins

Beloit, Wisconsin — Indianapolis, Indiana
September 28, 1883 — December 8, 1951

America is rapidly becoming conscious of the splendid achievements of such great organizations as Eli Lilly & Company, Monsanto Chemical Company, Upjohn, Parke, Davis & Company, and others, because of their research and development of the "wonder drugs," but few Americans realize that thousands of their fellow Americans, generally unknown to other than a few of their fellow workers, spend their lives pursuing the elusive clues that lead to the discoveries that literally remove the terror by day and the pestilence that walketh in darkness. Such a worker was Francis Eugene Bibbins who devoted forty-five years of his life to service with Eli Lilly & Company.

Dr. Bibbins was born on September 28, 1883, in Beloit, Wisconsin. He attended the elementary schools in Beloit, and Kankakee, Illinois, and was graduated from the Delphi, Indiana, High School. He then went to work in Delphi as a butcher boy, but through the kindly interest of a local druggist he was encouraged to work in his drug store and begin the study of pharmacy. Purdue University at that time offered a two-year course in pharmacy and young Bibbins decided to enter Purdue, although it would be necessary for him to earn his way while he studied. In December, 1903, six months before he expected to graduate, Eli Lilly & Company requested that the Purdue College of Pharmacy recommend to them a promising young man, and young Bibbins received the call. He accepted the position with considerable misgivings because of the fear that he would not be able to graduate with his class, but in June, 1904, the Dean of the College of Pharmacy wrote for him to report for graduation and he received the Bachelor of Pharmacy degree. He began his work at Lilly's as a pharmacist and became the Chief Pharmacist in 1913. At the time of his retirement in 1948 he was Head of the Formula Control Department. Dr. Bibbins passed away on December 8, 1951.

Recognition of Dr. Bibbins' ability came early for in 1927 he was chosen President of the Board of Trustees of the Indianapolis College of Pharmacy, now the Butler University College of Pharmacy, and he served in this capacity until 1945. He was made a member of the U. S. Pharmacopoeia revision committee in 1930, and he later served on the National Formulary revision committee. The Indianapolis College of Pharmacy conferred the honorary Bachelor of Science degree on him in 1929, and in 1942 Purdue honored him with the Doctor of Science degree. Following his retirement in 1948 he was made an honorary member of both the American and the Indiana Pharmaceutical Associations.

Long a member of the American Pharmaceutical Association, he was chairman of its Science Section in 1934 and secretary of this Section from 1935 to 1943. He was also a member of the American Association for the Advancement of Science and the American Chemical Society, and an honorary member of the pharmaceutical fraternity, Kappa Psi. Dr. Bibbins joined the Indiana Academy of Science in 1940, but he had not been active in its work.

Dr. Bibbins was an excellent citizen, active in church work and Masonry. He had a deep and sincere interest in Masonic organizations, being a member of the Blue Lodge, the Keystone Chapter of the Raper Commandery, Scottish Rite, and the Shrine. He was also a member of the Columbia Club and the Indianapolis Athletic Club. As a scientist he made his contribution through pharmacy to the tremendous strides in health improvement so apparent throughout the United States today.

CHARLES HIRE

Columbia City, Indiana	Bloomington, Indiana
December 1, 1887	September 8, 1952

With the sudden death of Dr. Charles Hire Indiana University lost one of its outstanding teachers and a prominent alumnus. He was distinctly a Hoosier-trained scientist for he received all his formal education in the State. He was born in Columbia City on December 1, 1887, and after completing his public school education he taught for two years in the rural schools of Whitley County, and also served as principal of Churubusco High School from 1912 to 1914. Several years of his undergraduate study were worked in between his years of teaching and he finally received the A.B. degree from Indiana University in 1915.

Following his graduation he became a laboratory assistant in physics at Indiana University for the next two years and completed the work for the M.A. degree in 1917. With the entrance of the United States into World War I in 1917 he volunteered and entered the First Officers Training Camp and was commissioned a First Lieutenant. In December, 1917, he went to Europe as a member of the American Expeditionary Forces, saw service in France as a Captain in the Ordnance Department, and returned to the United States in July, 1919. He accepted an instructorship in the Department of Physics at Indiana University that Fall and four years later he was promoted to Assistant Professor. In 1925 he was appointed Head of the Department of Physical Sciences in the Kentucky State Teachers College at Murray, Kentucky, which position he held for the next eighteen years. During this time he completed the work for the doctorate in physics and received the Ph.D. degree in 1927 from Indiana University. He also served as Dean of Men at Murray from 1926 to 1929, and directed their Summer Session in 1931.

Dr. Hire returned to Indiana University in 1943 to be supervisor of physics instruction in the Army Specialized Training Program and the following year he was appointed Acting Head of the Department of Physics for that year. Since 1945, up until the time of his death from heart attack on September 8, 1952, he was Professor of Physics.

Dr. Edward Garfield Mahin

Professor Hire was a Fellow in the American Association for the Advancement of Science and a member of the American Physical Society, the American Association of Physics Teachers, the American Association of University Professors, and the Indiana and Kentucky Academies of Science. He was President of the Kentucky Academy of Science in 1939-1940, and edited its Quarterly Journal from 1941 to 1943. He joined the Indiana Academy of Science in 1944. He had membership in both the National and Kentucky Educational Associations. He was also a member of Sigma Xi and was listed in *Who's Who in America*.

In research Dr. Hire had done work on the Brownian movement, interfacial surface tension, and capillary action and the absorption of air on glass. He was the author of two textbooks, Laboratory Studies in College Physics and College Physics for General Education.

Dr. Hire was primarily a teacher rather than a laboratory technician and he was a most interesting lecturer to beginning students in physics and attracted quite a large number to his classes. The University recognized this skill and placed him in charge of elementary physics courses. He insisted on hard work on the part of the student as well as for himself and he succeeded in holding the respect and friendship of his students despite his rigorous insistence on high standards and hard work. Also during the past few years Dr. Hire had built up quite a reputation over the State as a popular lecturer on atomic energy.

Amateur photography interested Dr. Hire and he possessed considerable photographic equipment. Also he was interested in building houses and he had built two while living in Kentucky, and it was while working on one in Bloomington that he possibly overtaxed his strength and the fatal heart attack resulted.

EDWARD GARFIELD MAHIN

Lafayette, Indiana	South Bend, Indiana
August 16, 1876	February 4, 1952

During the past twenty-five years Purdue University has developed its graduate study to the point that it now has one of the largest graduate schools in the United States. The first Ph.D. degree ever given by Purdue was conferred on D. T. McDougall in 1897, in botany, under the direction of J. C. Arthur, and the second was not conferred until 1928, although four Doctor of Engineering degrees were granted, one each in 1904, 1908, 1914 and 1920. In the Spring of 1922 the Purdue faculty "directed that a committee of the faculty be appointed to study the various problems and to outline the several necessary steps for the organization, establishment and maintenance of a graduate school whose functions shall be extended as rapidly as possible." President Edward C. Elliott, who came to Purdue in the Fall of 1922, accordingly, in 1924, appointed a Committee on Graduate Study composed of seven professors and the Registrar, with Dr. Edward G. Mahin, of the Department of Chemistry, as chairman. This Committee during the next year made an extensive and intensive study of graduate policies and procedures followed in other universities of the

United States and made its Report in the Spring of 1925, a Report approved by the Trustees in April, 1925, and adopted by the faculty in June, 1925, on which the present Graduate School at Purdue is founded.

Edward Garfield Mahin was born near Lafayette, Indiana, on August 16, 1876, and following the completion of the work offered by the public schools, he entered Purdue University and was graduated with the B.S. degree in 1901. He was immediately appointed an assistant in chemistry at Purdue and two years later received the M.S. degree and was promoted to instructor. In 1906 he entered Johns Hopkins University to do graduate study, was made a Fellow in 1907, and received the Ph.D. degree in 1908. He returned to Purdue as Associate Professor of Analytical Chemistry and in 1914 was made a full Professor. During the war period, 1917 to 1919, he spent the summers as metallographist at the United States Naval Engineering Experiment Station. In 1925 he resigned at Purdue to accept the first professorship in metallurgy at the University of Notre Dame and was made Head of the Department in 1932. He retired in 1949 and passed away on February 4, 1952.

Dr. Mahin enjoyed a national reputation as a chemist and metallurgist. He was author of numerous research papers in the leading chemical and metallurgical journals and he was also the author of five books. His Quantitative Analysis first appeared in 1914 and passed through four editions. He was joint author in 1923 with R. H. Carr of Quantitative Agricultural Analysis, and in 1929 his Introduction to Quantitative Analysis was published. He became a Contributing Editor to the Journal of Chemical Education in 1925 and continued for many years. His research was in analytical chemistry and in the hardness, carburization and inclusions in steel. He presented twelve papers and nine joint papers before the Indiana Academy of Science of which fourteen were published in the Proceedings of the Academy. His Presidential Address to the Academy, Metals and Microscopes, gave a very comprehensive survey of the knowledge of metals up to the year 1928. His first paper was published in 1902 and he continued active publication during the next forty years.

Dr. Mahin was very active in the American Society for Metals, being chairman of its Committee on Constitution and By-Laws in 1938-39, a member of its publications committee from 1941 to 1944, serving as chairman the last year, and a Trustee from 1947 until his death. He was also a member of the American Institute of Mining and Metallurgical Engineers, the American Foundrymen's Association, the American Society for the Promotion of Engineering Education, the British Iron and Steel Institute and the British Institute of Metals. For a number of years he was a member and Fellow of the American Association for the Advancement of Science. Dr. Mahin joined the Indiana Academy of Science in 1902, became a Fellow in 1922, and was its President in 1928. He served on various committees, among them the Academy Research Committee for twenty-five years, and he was a member of the Research Grant Committee at the time of his death.

Among his honors were his memberships in Phi Beta Kappa, Sigma Xi, Tau Beta Pi and Phi Lambda Upsilon. Notre Dame honored him with the Distinguished Teacher Award and, in 1950, Purdue conferred on him the honorary Doctor of Science degree. He has been listed in *Who's Who in America* for many years.

Edward G. Mahin was a man who had decided convictions and was fearless in maintaining his stand on what he believed to be right. He believed in and practiced high educational standards and he possessed considerable administrative skill and ability. These qualities secured for him the highest respect of his students and colleagues, and he was recognized as an outstanding member of the Faculty both at Purdue and Notre Dame. He brought honor to both institutions. The Indiana Academy of Science recognizes him as one of its scientific leaders and faithful servants.

ALFRED PETER POORMAN

Altamont, Illinois	Lafayette, Indiana
February 13, 1877	February 12, 1952

When Alfred Peter Poorman came to Purdue University in 1909 the University enrolled fewer than two thousand students and at the time of his retirement in 1947 the number of graduate students alone enrolled exceeded that number. During that time, one of the most remarkable periods in mass education, Professor Poorman had seen and helped Purdue to develop into one of the great engineering schools of the world.

Professor Poorman was born at Altamont, Illinois, on February 13, 1877, and he completed all the public school work offered by Altamont in 1894. For several years thereafter he helped his father operate two farms near Altamont. Desirous of continuing his education he entered the Academy of the University of Illinois, graduated in 1903, and then began his course in civil engineering and received the degree, Bachelor of Science in Civil Engineering, with honors, in 1907. That Fall he went to the University of Colorado as an instructor in civil engineering and by 1909 he had completed the required work for the Bachelor of Arts and Civil Engineering degrees at that university. He spent the Summer of 1909 as a hydrographer on the Wind River Indian Reservation, in Wyoming, and then came to Purdue in September, 1909, as Assistant Professor of Applied Mechanics. In 1917 he entered the United States Army and in June, 1918, he went to France as a captain with Company A, 29th Engineers, stationed at Langres, France. He served as a Supply Officer of the General Headquarters, American Expeditionary Forces, until June, 1919. Following his return to the United States he again took up his work at Purdue, was promoted to Associate Professor in 1920 and two years later to Professor of Applied Mechanics. He was Acting Head of the Department of Applied Mechanics from 1942 to 1944 and retired as Emeritus Professor in 1947, after thirty-six years of service to Purdue. Stricken suddenly with acute meningitis on February 11, 1952, he passed away the next day, on the eve of his 75th birthday.

Professor Poorman was active in several professional engineering societies. He helped to organize and was the first chairman of the Applied Mechanics Division of the Society for the Promotion of Engineering Education, now known as the American Society for Engineering Education, and was a member of its Council from 1932 to 1935. The American Society of Civil Engineers made him a life member in 1943. He was also a member of the American Concrete Institute, the American Society for Testing Materials, The American Association for the Advancement of Science, and the American Association of University Professors. Among his honors were memberships in Tau Beta Pi, Sigma Xi, Chi Epsilon and Scabbard and Blade. He was also listed in *Who's Who in America.* He became a member of the Indiana Academy of Science in 1924 and was made a Fellow in 1935.

Professor Poorman did not publish many articles in professional journals but he was the author of two widely used textbooks, one on Applied Mechanics in 1917, and the other on Strength of Materials in 1925. Both books passed through four editions.

A man of pleasing and gracious personality, Professor Poorman was an effective teacher who had an intense interest in this students and in his fellowmen in general. He found time to work for his community, his church and his family. A member of the Official Board of the Trinity Methodist Church, he was also active in Sunday School work where he attracted many who came to hear his interesting discussions of Biblical history and allegories. Alfred Peter Poorman leaves behind him a record of devoted service to his community and to many generations of Purdue students. His was a full and productive life.

HARLEY WESLEY RHODEHAMEL

Indianapolis, Indiana — Indianapolis, Indiana
December 6, 1884 — April 8, 1952

Within a period of less than a year the Indiana Academy of Science has lost three members, John Shepard Wright, Francis Eugene Bibbins and Harley Wesley Rhodehamel, whose careers were remarkably similar in that each graduated from Purdue and each devoted his whole professional life to humanitarian service with Eli Lilly and Company and each retired as director of his special field with that great organization. Harley Wesley Rhodehamel, the last to pass away, retired as executive director of research and control in December, 1949, and died after a short illness on April 8, 1952.

Mr. Rhodehamel was born in Indianapolis on December 6, 1884, and received all his public school education there, graduating from Manual Training High School in 1904 at the head of his class. He then entered Purdue and was graduated with the Bachelor of Science degree in chemistry three years later. He immediately entered the service of Eli Lilly and Company as a chemist, worked successively in the drug and chemical stores department, the production offices, the engineering division, and the analytical department until 1915 when he was made director of the research division. In 1947 he was appointed Executive Director of Research and Control, and he retired two years later after forty-two years of service with the Lilly organization.

As a biochemist Mr. Rhodehamel made important contributions to many Lilly products, especially Iletin (Insulin, Lilly), liver extracts and barbiturates. He also designed equipment for chemical research and production. For many years he was the company representative in all its dealings with the Council of the American Medical Association. His principal research was in the manufacture and purification of insulin, and the development of liver extracts, parathyroid extract and antibiotics. His international interest in chemistry was reflected by his memberships in the American, German and Swiss Chemical Societies. He was also a member of the American Pharmaceutical Association and a Fellow of the American Association for the Advancement of Science. He joined the Indiana Academy of Science in 1940. He was also active in the Indianapolis Chamber of Commerce and he was a charter member of the Scientech Club of Indianapolis.

A great lover of music he played both the piano and violin, and his hobbies were photography and the technical side of radio and television, at which he worked in his own well equipped workshop. He was devoted to his home, his family, and his friends, and he was particularly interested in any movement for the welfare of children.

An excellent scientist and executive with a deep interest in the welfare of his fellow workers and mankind in general, untold thousands owe much to Harley Wesley Rhodehamel's forty-two years of unselfish, devoted service and research in relieving human suffering and fear. The safety and happiness of millions have been increased through the labors of this modest and unassuming scientist.

ERNEST RICE SMITH

Cameron, Missouri — Ithaca, New York
July 3, 1891 — March 21, 1952

The history of geology in Indiana extends over more than a century, for the first special geological survey of the State was made in 1837-1838 by David Dale Owen. At that time Indiana was only one of fifteen states conducting geological surveys and out of all that activity came the organization in 1840 of the Association of American Geologists and Naturalists, which became the American Association for the Advancement of Science in 1848. Many prominent scientists in Indiana have been active at one time or another in geological work, among them David Dale Owen, Richard Owen, E. T. Cox, Ryland T. Brown, John Collett, Josiah T. Scovell, Willis S. Blatchley and John C. Branner, and more recently Clyde A. Malott. Another Indiana geologist who has wielded considerable influence as a geologist, particularly in the training of geologists, was Ernest Rice Smith who came to DePauw University in 1921 to organize the Department of Geology and during his twenty-six years of service at that institution trained a comparatively large number of young men who continued their studies to the doctorate and now hold important positions in American universities and with the great oil companies.

Ernest Rice Smith, or "Rock" Smith, as he was known to his friends, was a man of marked personality and to some of his geology major students would rank as the most remarkable man they had ever known. Only those who were willing to observe the highest standards of scholastic achievement and to endure the hardships of long and arduous geological field trips could expect to obtain the geological blessing of Professor Smith. He loved the hills and valleys and he did not spare his students and he did not spare himself, but he secured and retained a remarkable and enduring loyalty from his major students.

He was born in Cameron, Missouri, on July 3, 1891. Upon completing his public school education he entered Oberlin College and was graduated in 1912 with the Bachelor of Arts degree. He spent the next two years at Fisk University as an instructor in geology and mathematics and then entered Cornell University. He became a graduate assistant in mineralogy in 1915, and later a Goldwin Smith Scholar and Fellow and an instructor in geology. The year 1917-1918 he worked in Panama and Costa Rica as a petroleum geologist with the Sinclair Oil Company, resigning to enter the Army. He served overseas as a lieutenant and following the Armistice spent some time at the Sorbonne. On his return to the United States in 1919 he went to the University of Michigan as an instructor in geology, and the year following he returned to Oberlin College as an Acting Assistant Professor of Geology. He came to DePauw in 1921 as an Assistant Professor of Geology and in time became Professor and Head of the Department of Geology. Due to a serious automobile accident in January, 1942, which kept him out of the classroom for eighteen months and from which he never fully recovered, and several heart attacks later, he was forced to retire from active teaching in 1947. He and Mrs. Smith then went to Ithaca, New York, where Professor Smith became associated with the Paleontological Research Institution of Ithaca, of which he was a Trustee at the time of his death, on March 21, 1952.

Professor Smith was an active geologist who delighted in long field trips. He derived the greatest of pleasure, as long as he was able, in attending meetings of the Geological Society of America, the Association of Petroleum Geologists and the American Association for the Advancement of Science, where he met many of his former students with whom he kept in close touch through regular correspondence and a voluminous, illustrated Departmental News Letter sent out at regular intervals for a number of years. He also held membership in the Crystallography Society, the Geological Society of France, and the Michigan and Ohio Academies of Science. He joined the Indiana Academy of Science in 1921 and became a Fellow in 1933. He was also a member of Phi Beta Kappa and Sigma Xi. The geology library at DePauw, built up through his efforts, is now known as the E. R. Smith Geology Library and is housed in the Department quarters.

Not only was "Rock" Smith an excellent teacher and field geologist but he also had done research in Pliocene and Pleistocene paleontology, marine mollusks, and sedimentation, and in later years, quicksand. He published occasionally in geological journals. In the Indiana Academy of Science he was active and frequently presented papers, of which eight were published in the Proceedings. He served on the Academy Committee for Archaeological Survey from 1930 to 1935, and on the Committee for Publication of the Proceedings from 1934 to 1937. He was also a Sectional Chairman several times.

Professor Smith was not only an excellent teacher and geologist but he was also a man of sterling character who had ideals and sincere convictions and the courage to stand for what he believed to be right. He was interested in a better community and at one time was really active in Boy Scout work. Ernest Rice Smith lived a full and effective life.

JESSE ELMER SWITZER

Waynetown, Indiana — Bloomington, Indiana
September 26, 1876 — May 29, 1952

When Jesse Elmer Switzer passed away on May 29, 1952, from a concussion following a fall from a scaffold while painting the eaves of his house, the Academy lost one of its most active older members. He had served as chairman of the Membership Committee for six years, from 1945 to 1950 inclusive, and was Vice-President of the Academy in 1951. He was very conscientious and effective in his work for the Academy, which he had joined in 1923. He became a Fellow in 1926.

Dr. Switzer was a native of Waynetown, Indiana, and was born on September 26, 1876. For a number of years after completing his public school education he taught in the grade and high schools of the State, and began his college education at Central Michigan State College. In 1911 he received the Bachelor of Arts degree at the University of Chicago, and the Ph.D. degree in Geography was conferred on him in 1923 by Clark University.

Immediately following his graduation from the University of Chicago he went to the North Dakota State Teachers College, at Valley City, as Head of the Department of Geography. He remained there ten years and resigned in order to complete the work for the doctorate. He came to Indiana University in 1923 as Assistant Professor of Geography, was promoted to Associate Professor two years later, and became Professor of Geography in 1936. He retired as Professor Emeritus in 1947. Dr. Switzer had spent a number of summers as instructor in geography at other institutions, two at Yale University, three at Peabody College, two others in North Dakota and Ohio, and one at the Pennsylvania State Teachers College at California, Pennsylvania.

He had been a Fellow of the American Association for the Advancement of Science for over twenty-five years, and he was a member of the American Meteorological Society and the Society of Professional Geographers. From 1943 to 1946 he was a Director of the National Council of Geography Teachers and he had served as president of its Indiana Section. At Indiana University he had been president of the Bloomington chapters of Sigma Xi and the American Association of University Professors. A very active member of Kiwanis International he had been president of the Bloomington Club and he was a Lieutenant Governor of the Indiana district at the time of his death.

Dr. Switzer was a sympathetic and earnest teacher who was always anxious to be helpful to his students. He believed in and lived the ideal of service and through his friendly and cooperative efforts in the service club, the University, and his church, he helped to make Bloomington a better place in which to live. Primarily a teacher he nevertheless published occasionally in professional journals and he also presented a number of papers before the Academy, four of which were published in the Proceedings. In his death the Academy has lost a conscientious, faithful worker, and his community has lost an excellent citizen.

PRESIDENTIAL ADDRESS

The Role of Mathematics in Science

P. D. Edwards, Ball State Teachers College

When mathematicians are assembled to hear a talk by one of their own kind it is expected that the speaker define his terms. If there be terms that cannot be defined they should be listed. It is generally accepted that mathematics begins with a set of postulates, definitions, and undefined terms. Consequently I should define the terms mathematics and science. A formal definition of either would be unsatisfactory. Each of you is engaged in some phase of scientific work and any definition which I might give of science most surely would fail to satisfy some of you. I list it as an undefined term, hoping that in a general way we hold like views as to the broad meaning of the term.

Mathematics has been defined in many ways. Bertrand Russell in his Philosophy of Mathematics defined mathematics as ". . . the subject in which we never know what we are talking about, nor whether what we are saying is true." While the statement has brought forth many different reactions, I will let it stand without comment for the present. I shall use the term more in the common sense of a system of symbols and laws of operation. This has been expressed by the statement that mathematics is the science of drawing necessary conclusions.

While not attempting to define the term science I believe we can agree that in the development of the various fields of science four phases are recognizable. First is the observation and recording of facts. Second is the formation of theories based on generalizations of the observations. Third is the drawing of necessary conclusions which must follow if the statements of theories represent basic laws. Fourth is the testing of our conclusions by controlled experiments.

Recognizing the importance of each part to the development of the whole I wish to avoid giving the impression that I regard one part as more scientific than another. A good example of the observation and recording of facts is the work of the State Flora Committee. The publication of the work of this committee in the PROCEEDINGS has placed the Indiana Academy of Science in a position of leadership among all state academies in this field. The work on the fauna of Indiana is less complete but important contributions have been published by the Entomologists.

The biological sciences are not the only ones in which the collection and recording of data is a prominent part of the work. Perhaps the largest organization of observers is in the field of meteorology. The importance of the coordination of workers in this field came to public attention during World War II. World wide organizations of observers also exist in Seismology and in the oldest of all sciences Astronomy.

To illustrate the second phase I turn to the field of Astronomy. From the dawn of history men have observed the stars and the motions of planets, moon, and sun. Many theories concerning the celestial bodies were formulated. About 150 A. D. Ptolemy developed his geocentric theory which influenced the thinking of scientists for more than a thousand years. It was a theory of structure, attempting to explain how the bodies moved. It was not a theory which explained the motions on the basis of an underlying physical law. The same can be said of the theory of Copernicus which was published shortly before his death in 1543. His theory was less complicated from the standpoint of the mathematics involved but it, too, was only a theory of how the motions were related. The classic example of the organization of data of observation is the work of Kepler (1571-1630) who spent the major portion of his adult life studying the records of observation left by the greatest observer of all time, Tycho Brahe. Out of a lifetime of work Kepler gave the world three results which today are known as Kepler's Laws. The first stated that the orbits of the planets were ellipses with the sun at a focus. The second stated that the planets moved at varying speeds so that the area swept over by a line joining sun to planet would be proportional to the time. The third stated that the cubes of the distances of any two planets from the sun are to each other as the squares of their periodic times. Kepler seems to have taken especial delight in the third law. Of it he wrote: "The die is cast, the book is written, to be read either now or by posterity, I care not which; it can await its reader; has not God waited six thousand years for an observer?"

It is often said that without the work of Appolonius on Conics, there would have been no Kepler. Like Ptolemy and Copernicus, Kepler attempted to explain how the planets move. He did not attempt to state the physical law that gave the cause of their movement. With Newton the science of Astronomy entered the third phase. Beginning with Newton's statement of the universal law of gravitation and using the methods of Calculus it is possible to contain Kepler's laws not in twenty years but in less than two hours.

The third phase of science which I listed was the drawing of necessary conclusions. It is in this phase that mathematics plays its most important part. Some would even identify this process with the very definition of mathematics. However the work of Kepler was also mathematical in character but based on a portion of mathematical theory which was not adequate to perform the task accomplished by Newton. To this phase of science and especially the work of Newton I will return.

The fourth phase of the development of a science is the testing of predictions by experiment. In the field of Botany, the geneticists have given mid-west America hybrid corn. This is not the result of blind experiment but of planned experiments based on theories concerning the fundamental laws of inheritance. In the field of Chemistry we have arrived at the point where in many cases it is possible to predict the properties of a chemical compound before the compound has been synthesized. Progress has been made in this line in drugs, plastics, and synthetic fibers.

The worker needs to continue to be an observer of facts. Important discoveries continue to be made by the study of experiments which give unexpected results. Today when we ride in our automobiles we are protected by safety glass. The basic discovery which led to its invention was not the result of a planned experiment but instead was the result of an accident. It may be taken as a fundamental axiom of all science that if our basic assumptions include a true statement of all the physical laws involved and if our reasoning is valid, then there can be no deviation between actual and predicted result. The surprise result can occur only when there is an error in our reasoning or where there are factors present which were not included in our statement of conditions. The latter is the more frequent case. Expressed mathematically, we have omitted terms from our equations which are not negligible.

Returning to the definition of mathematics given by Russell we find that it makes sense if we regard mathematics as restricted to the mechanics of drawing conclusions from a set of symbols. The differential equation $dx/dt = kx$ expresses the law that the rate of change of a quantity x is proportional to the amount of the quantity x. The solution may be found by the sophomore student of Calculus without any reference to what sort of quantity is represented by x. In fact he need not know that the law is ever true. His conclusion can be stated that if the law expressed by the differential equation is ever true then the value of x at any time is given by the law $x = Ce^{kt}$ where C is the value of x when $t = 0$. The Actuary calls this the compound interest law. The Biologist calls it the law of growth. The same law arises in other fields and is known by other names. The mathematician performs an operation on a set of symbols. He need not know the meaning of the symbols, nor whether the condition stated is ever true. Of one thing he is certain. If the first equation is true the second must also be.

Basically pure mathematics is abstract. We humans share a common trait of thinking in concrete situations. We want meaning in our symbols, but the full power of mathematical reasoning can be realized only to the extent that we are able to substitute symbols for ideas and then draw valid conclusions by performing operations on the symbols. The concept of a one to one correspondence between classes is fundamental. The words of our number system are perhaps the first step in the long road of successive abstractions that each of us must travel in our mastery of mathematics. A child learns that two books added to three books makes a total of five books, that two apples added to three apples makes a total of five apples, etc. The idea that two plus three equals five is abstract. Each of us passed through a stage at which we could add small sums if each bore a label but found the process difficult when the sums were not so labeled.

It is often stated that the greatest invention of man was the symbol for the number zero. It made possible the arabic system of numerals. With the arabic numerals it was possible to construct simple algorithms whereby the four fundamental operations could be performed directly on the symbols without the use of objects. To appreciate the meaning of this try to extract the cube root of 3 correct to four significant places using the Roman numerals. It is possible but not easy. It is interesting to speculate on the possible attainments of such mental giants as Archimedes had they possessed our present system of writing numbers. This is also the secret of the power of algebraic symbols.

The development of mathematics has been closely linked with advances in the sciences of Physics and Astronomy. Neither science has ever advanced beyond the stage of the available mathematical theory. In some cases the needed mathematics has been invented by the scientist in order to proceed with his scientific studies. The outstanding example is of course Sir Isaac Newton who was interested first of all in Physics and Astronomy. Had he not invented a new and powerful tool his scientific work could not have gone much beyond his notable predecessors: Ptolemy, Copernicus, and Kepler. Symbols could readily be written for forces, accelerations, velocities, and coordinates of position. The thing needed was a set of operations which could be performed on the symbols in an equation which would give other symbols which in turn could be interpreted as physical states. Newton's Fluxions accomplished this purpose.

The two operations which he defined are known as differentiation and integration. With these operations and three basic postulates which we know as Newton's Laws of Motion, plus his Universal Law of Gravitation the whole of classical mechanics followed. At approximately the same time, Liebnitz in Germany was working in the field of Geometry. Needing more general methods of finding tangents than were available in the Geometry of Descartes, he, independently of Newton, invented the same two transformations. The work of the two men differed in notation and in purpose but the resulting abstract mathematical operations were identical. The importance of this feature cannot be overemphasized. The laws of operation on symbols are independent of the subjective content of the symbols. It comes very close to the heart of mathematics and explains its power. Recall that in 1700 virtually nothing was known of electricity and the foundations of modern chemistry had not been formulated. Yet this abstract theory for the manipulation of symbols contains the most useful tools for the investigation today of problems in electrical theory and in Physical Chemistry.

Following Newton and Leibnitz there was a period of more than a century during which the pure mathematicians flourished and the Calculus expanded far beyond the needs of any scientist working in other fields. In most areas researches in pure mathematics kept well ahead of the applications. Foundations were laid for new and specialized fields. It was during this period that the foundations of Differential Equations, Calculus of Variations, Infinite Series, and other divisions of Analysis were laid by men from Euler to Weierstrass who were interested in abstract mathematical ideas. There were some notable exceptions. Fourier was first of all a Physicist. The series known by his name was invented to assist in the development of his theory of heat. Today Fourier series are of even more importance to the electrical engineer than to the heating engineer.

In 1871 when Clerk Maxwell published his treatise on Electricity and Magnetism the mathematical tools were available for him to write down his famous Field Equations. These appeared to be based on sound postulates. However the equations seemed to give too much. Solutions appeared for the equations that were not matched by any known physical phemenan. The story of Hertz and his discovery of wireless waves is known to you. Today radio and television are a part of our everyday life. Whether or not the technical developments could have been made without the beginning in a set of differential equations is uncertain. At least the fact remains that the equations were written and solved first and that Hertz's basic discovery was inspired by a set of equations.

In our own generation another mathematical equation has played a vital role in the making of history. I refer to the equation $E = mc^2$ which was first deduced by Einstein. It was known and accepted by mathematicians and physicists for a quarter of a century before the first successful attempt was made to release energy by the destruction of matter.

These two examples serve to emphasize the point made by Benjamin Pierce when he defined mathematics as the science of drawing necessary conclusions. One might add that at least in the case of Maxwell the definition of Bertrand Russell applies. Certainly when Maxwell wrote his equations he did not have radio and television in mind. Another example of the drawing of necessary conclusions by mathematical analysis is the discovery of the planet Neptune. The Englishman Adams and the Frenchman Leverrier each computed the orbit of an hypothetical planet which was assumed to exist and be the cause of the discrepancy between the actual and theoretical orbit of Uranus. Adams completed his work first but was unable to interest any English astronomers in seeking the planet. Leverrier was more fortunate. Neptune was first recognized by the German astronomer Galle who found the planet in less than half an hour within less than half a degree of the position predicted by Leverrier.

There have been periods in the history of science when the advances in science seem to overtake the inventions of the mathematicians. The period of Newton was one. Today problems arise in radar, television and other high frequency circuits which give rise to non-linear differential equations. The general theory is extremely difficult and until recently the equations were not considered either important or interesting. Today they are important and particular equations are being solved, often by methods of numerical approximation. Perhaps more general methods of solution will be found. At any rate the present lack of satisfactory general solutions emphasizes the close connection between physical and mathematical theory. It has been suggested by at least one competent physicist that the basic equations of physics must be non-linear, and that mathematical physics will have to be done over again. Should that prove true the analysts of the next century will face harder problems than have been solved to date and the result may be a system of mathematics quite different from that known today.

Most of you have some acquaintance with the elementary theory of vectors. A few of you may be familiar with some of the earlier theories of multiple algebras. Hamilton's quarternions are perhaps the best known of the early attempts to produce a system of this type. The vector analysis developed by J. W. Gibbs in the 1880's is still the most important of the simpler types. The development from vector to matrix and tensor was rapid and by 1900 both theories were well developed. However up until the second world war neither theory had much practical value to the engineer. As a graduate student I learned the theory of matrices.

But I also learned the difficulty of applying that theory. The calculation of the inverse of a square matrix of order two or three was fun. To calculate the inverse of one of order ten or twenty appeared impossible because of the time involved. The modern electronic digital computer has changed all that and matrices have become one of the working tools of engineering research. Much of the progress made in the development of jet planes that fly faster than the speed of sound would have been impossible without the mathematical theory of matrices.

As has happened so often in the history of the development of mathematics, matrices are proving of equal value in totally different fields. Today there are a number of electronic computers in use, each staffed by a working crew of from ten to thirty men, including mathematicians, electrical engineers, and technicians. At the meeting of the Econometric Society last September it was reported that the inverse of a square matrix of order 190 had been computed in an elapsed time of only 47 hours. This problem had arisen not in physical science but in economics. Had the problem been attempted by the methods discussed in courses in elementary theory of equations a little calculation soon reveals that the number of sheets of paper needed would far exceed Edington's estimate of the number of electrons in the known universe.

The present importance of computational methods gives emphasis to the statement made more than a century ago by the great German mathematician Gauss: "Mathematics is Queen of the Sciences and Arithmetic is the Queen of Mathematics. She often condescends to render service to astronomy and other natural sciences, but under all circumstances the first place is her due."

From the time of Euclid to the early part of the seventeenth century Geometry was regarded as an example of a complete and perfect mathematical theory. The work of Appolonius of Perga gave us all the properties of the conic sections almost seventeen centuries before they were applied to the theory of ballistics and through astronomy to the practical art of navigation. Then came the analytic geometry of Descartes, the Projective Geometry of Pascal and Desargue, the Descriptive Geometry of Monge which for a time was classified as a military secret by the French. Nor was the plane geometry of Euclid to continue to appear as a finished product. The number of new theorems stated by Steiner alone far outnumber the list in Euclid's Elements.

Perhaps the most important invention in the field of Geometry was the invention of the Hyperbolic Geometry by the Russian, Lobatschewski, and the Austrian, Bolyai. Paradoxically the system has little practical value. It is true that the addition of vectors in the hyperbolic plane can be made to yield the Fitzgerald contraction formula which is useful in Relativity. The importance of the invention lies in the effect it has had on the development of Geometry. It was a challenge to the accepted way of thinking to be forced to admit the existence of two self-consistent but mutually contradictory sets of theorems. Geometry ceased to be a branch of physical science and became a part of abstract logic. The latter part of the nineteenth century and the first half of the twentieth has seen the development of much that today exists as so-called pure mathematics. Differential Geometry, Algebraic Geometry, Analytic Projective Geometry, and Topology all show healthy active growth. Yet there is a strong suspicion that like the pure theory of matrices of 1900 these too may become the applied mathematics of the next half century.

In conclusion let us ask again what is the role of mathematics in science. One answer could be given by listing the various subdivisions of mathematics that are used by scientific workers in various fields. The list would be long, even for some of the sciences which we ordinarily think of as non-mathematical. For other sciences the list would be almost a complete roster of the subdivisions of mathematics. Instead of answering in this way I prefer to ask what there is about mathematics that gives the subject its peculiar power. I believe that the answer may be found at least in part in two fundamental concepts. The first is the concept of a one to one correspondence between a set of abstract symbols and the set of elements which form the body of subject matter of a science. The second concept is that which the mathematician calls a group. The group is defined as a set of elements and a law of combination, such that the result obtained by combining two elements of the group will itself be an element of the group. The precise definition contains a little more but the secret lies here.

Whatever the field of science may be and whatever the laws of change, one has but to discover a rule of operation on the abstract symbols in order that the details of the science may be matched in a one to one manner with the symbols.

Logically it should be possible to develop a mathematical system which has no possible use. It has appeared at times that such was the case but far more often the pure mathematics of one decade has become the handmaiden of science in the next.

ANTHROPOLOGY

Chairman: Mrs. George F. Martin, Newburgh, Indiana

Paul Gebhard, Indiana University, was elected chairman for 1953

ABSTRACTS

Agricultural ceremonies in Peru. T. J. Maxwell, Indiana University.—Throughout the Central Andes which lie in Bolivia and Peru, there is a strong development of ceremonialism which for the main part attempts to acquire divine favor for the benefit of the crops. The economy of these countries is highly dependent upon agriculture and by far the most numerous of the farmers are the Quechua and Aymara Indians. The ceremonies connected with each agricultural activity of the present day Indians have been compared with the ceremonies practiced by the Inca at the time of the Spanish conquest. The conclusion is that no ceremony has survived intact but that individual rites within the ceremonies of today are predominantly derived from the Inca. Spanish introduction has been limited for the most part to a few symbols from the Christian Church. The concept of earth mother which was known and venerated by the Inca has not only survived but increased in importance. There has been some identification of her with the Virgin Mary.

Experiments with beveled edged projectile points and knives. Arthur George Smith, Norwalk, Ohio.—The practice of beveling the edges of chipped artifacts can be traced back into Paleo-Indian time. The object of this practice was not to spin a shaft in flight but to form a more efficient tool. Experiments made by the writer using such points to tip arrows proved that the bevel had no effect on the flight, and that they were too large to penetrate tough hide.

The small beveled points common in the Southeast were made in this fashion for ease of fabrication from refractory stones.

The large types were knives and they are the most efficient stone tool for flaying animals, cutting up meat or woodworking. When dulled they were resharpened making the blade narrower and the edges steeper. Some were worked into a rounded end. These are not only a good scraping tool but ideal for cleaning fish. In fact these tools are a Stone Age Boy Scout knife.

The Aztec Festival of Xilomen. Paul Weatherwax, Indiana University.—This festival, which was held in the Aztec eighth month, beginning on June 25, was ostensibly a religious ceremony designed to honor the goddess of green corn, to bring the corn crop safely through the critical period of flowering and pollination, and to pacify the common people with free food and entertainment during the leanest month of the year. From incidental remarks made by the old Spanish chroniclers, however, it is believed that the celebration had still another significant function: it held the attention of the restless people at a time when it was imperative that they restrain themselves from wasting the green corn by eating it before it was fully developed.

New Material from Marion County, Indiana

VERNON R. HELMEN, Indianapolis

In 1948, a paper dealing with the archaeological manifestations of Owen County, Indiana, was presented before this Section of the Academy. A portion of that paper was devoted to the chipping patterns observed on amorphous flakes and speculation as to their formation and use (1). In 1951, William G. Haag published a paper concerning the flake artifacts found at the Jaketown site in Mississippi (2). The similarity of the artifacts from these two areas indicated a need for re-examination of worked flake artifacts in Indiana and for this purpose, material from Marion County, Indiana, was collected and examined.

In the past, these artifacts have been variously termed, "retouched flakes," "microflints," and "microflakes." The author would like to suggest the use of the term "used flakes" as this term would more accurately describe these artifacts and would avoid any connotation of size or specific manner of manufacture.

The used flake is characteristically an amorphous flake struck from a core, with one or more areas of fine marginal chipping on one face only (faceplan). Certain chipping patterns group used flakes into several categories: 1) those with a marginal line of very small, delicate chip scars along a relatively straight edge (D & I); 2) flakes having a line of flake scars on the margin of an excurvate portion of a flake (C); 3) flakes exhibiting an incurved or lunate margin heavily scarred by use (A & E); 4) flakes exhibiting a pointed marginal projection delineated by small flake scars (H & G); and 5) those flakes which combine several or all of the flake patterns described into a veritable prehistoric Boy Scout knife (F & B).

The method by which these artifacts were produced is still not clear. It is very probable that many of them were formed simply in the course of use, for continuous scraping of a sharp edged flint flake on a piece of wood will produce relatively fine chipping of the kind observed. Certain of these artifacts, however, were very deliberately chipped so as to provide a working edge, notably the graver types.

Unlike Haag's findings in Mississippi, the used flakes examined from Marion County are not restricted to a pre-pottery horizon. They occur in all horizons; however, from the superficial studies so far made in Indiana, they seem to occur most abundantly on pre-pottery and Early Woodland sites.

The question will be asked concerning the aboriginal use of these artifacts. While it is yet too early to do more than hazard a guess based on logic, the author would like to theorize that they were used for the shaping and carving of wooden, bone, and antler articles. Except in rare instances, only the non-perishable remains of prehistoric cultures are recovered by the midwestern archaeologist. Yet we can be quite sure that a group living in what is now Indiana would make use of the plentiful supply of wood for artifactual and artistic purposes, and we have many examples of their bone and antler craft. An analysis of scrapers and knives indicates that such forms would be of very limited use in executing fine detail in a wood carving. However, a sharp flake of accidentally appropriate form or intentionally shaped for use on a specific feature of a specific wooden article would be a handy and useful implement superior for such work to a scraper or a knife. This type of usage would also explain the very small size and peculiar shapes of some of these artifacts.

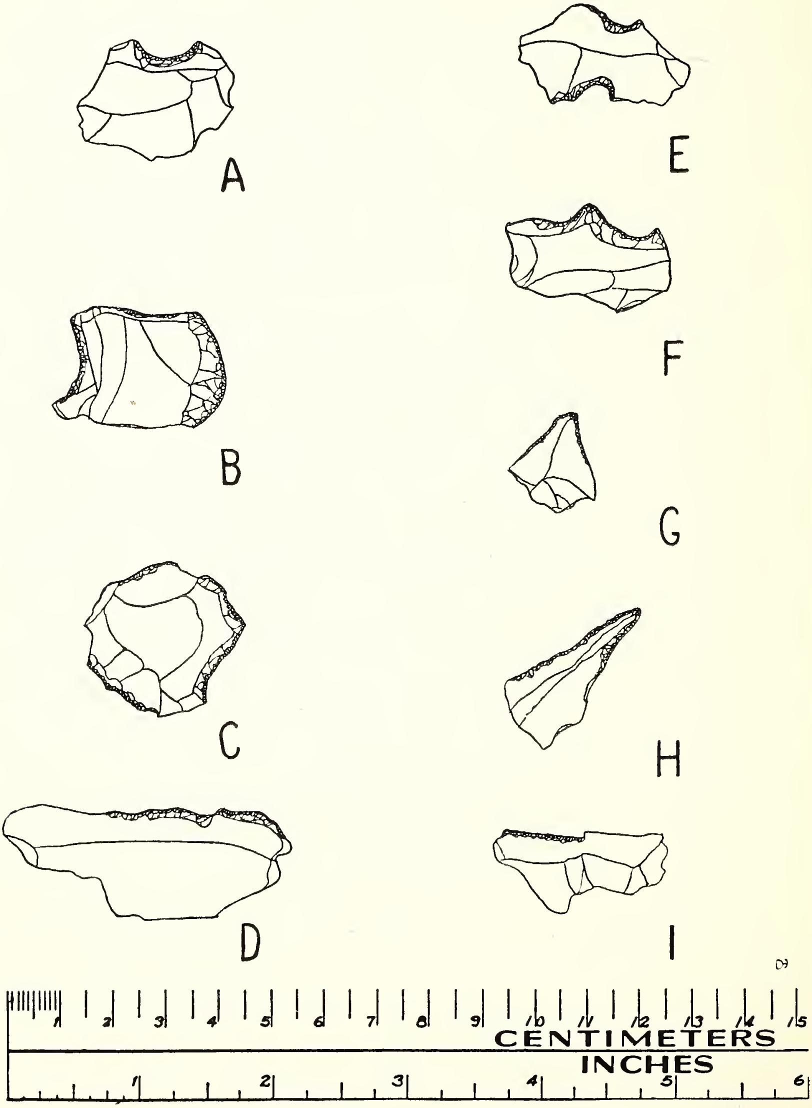

Figure 1

As to their profusion on many sites and widespread distribution, it may be surmised that on habitation areas littered with flint chips, such flakes could be quickly and easily found, fashioned, and used; and, as is usual with anything that is easily obtained, more frequently discarded and replaced than preserved for further use. It is hardly conceivable that any culture which used flint tools would overlook the plentiful supply of small, hard, sharp-edged tools ready-made as by-products of their flint industry. We may expect, therefore, that wherever we find flint chips on an aboriginal habitation site we will find that a certain proportion of them will show evidence of usage.

The present state of our knowledge concerning used flakes is very meager. This lack can only be overcome by intensive study of all flakes from a few sample sites so that the percentages of the various forms can be derived and related to the cultures represented. It is conceivable that in the light of knowledge so derived, the used flake may acquire a diagnostic significance. It is interesting to speculate about the flakes taken from mound fill and burials by excavators of the past. A re-examination of those flakes still available for study could very possibly reveal new data concerning some of the cultural values of prehistoric groups.

In areas of heavy modern occupation, many of the aboriginal sites have been so intensively cultivated and collected since the 19th century that most of the more easily recognized artifacts have been picked up, leaving only fire cracked rock and flint chips. This is the situation on many sites in Marion County. For the local archaeologist who is engaged in locating and recording the aboriginal sites of his area, any artifact that can help him in such a task is of importance; and it is in this area of endeavor that the used flakes have their most immediate usefulness.

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The Acorn in North American Indian Diet

Harold E. Driver, Indiana University

Many foods are indigestible or poisonous in their raw condition and must be processed before they can be eaten in quantity.[1] One of the best known examples is the tapioca plant *(Manihot utilissima)*, which was the staple food of tropical South America (28). The roots of this plant, which were the part eaten, contain a considerable quantity of hydrocyanic acid which must be removed before they can be consumed. This was done by grating the roots, soaking the pulp in water, and finally squeezing out the acid-bearing water with a woven cylindrical container made for the purpose. There is no single poisonous species in North America which was as indispensable to native diet as was tapioca in South America, but the acorn, which is normally unpalatable without special preparation, was widely eaten. It was probably of greater importance in Indian diet before Christ when farming was little known than it was after Christ when about half of the tribes farmed.

There are some 60 species of oaks in North America, most of which are grouped under a single genus, *Quercus*. Of these, acorns from 27 species are known to have been eaten by Indians (43). Acorns from all these species are known to contain tannic acid in varying amounts. The majority contain enough of this acid to prevent large quantities being eaten without first removing at least some of it. The main nutritive elements of acorns are starches and fats, with the former predominating in most species.

In aboriginal central California the acorn was a true staple, being eaten in greater quantity than the product of any other genus, animal or vegetable. The acorns were first cracked open with the aid of a small elongated stone for a hammer and a heavy flat slab of stone for an anvil. The nut meats were then ground with a mortar and pestle. The majority of mortars were hollowed out of stones of convenient size, but others consisted of man-made holes in the outcroppings of bed rock so common in the foothills of the Sierras. Still other mortars were made from a short section of oak log, while a few consisted of holes in a fallen oak log. Pestles were always of stone, roughly cylindrical, but with considerable variation in size and details of shape.

When the meal was ground sufficiently fine, it was taken to the bank of a stream where there was a handy water supply for the leaching process. Most frequently the meal was placed directly on the sand in a shallow depression or basin which had been prepared for the purpose. In southern California, however, the meal was placed in a porous basket. Then water was dipped from the stream and poured over and through the meal as in our manner of making drip coffee. Sometimes the water was heated by placing hot stones in a closely woven basket filled with the liquid. Warm water dissolved the tannic acid more readily, but if too hot carried away some of the fat which was a desirable nutritive element. Cold water took longer, but washed away none of the food value. This leaching process was repeated until the bitter taste of the tannic acid was eliminated. The meal was then ready for cooking.

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[1] This paper is a by-product of a forthcoming volume of North American Indian comparative ethnology which has been supported by two generous grants from the Wenner-Gren Foundation for Anthropological Research. This aid is gratefully acknowledged.

The most frequent cooking method was boiling to form a mush or gruel. The majority of California tribes boiled by placing hot stones, previously heated in a wood fire, into the water-tight basket containing the mixture of meal and water. This was a laborious process requiring frequent renewal of hot stones as well as stirring to prevent their burning the bottom of the basket. Tribes in the southern half of California boiled by placing a pottery vessel directly on or over a fire, just as we do in the modern kitchen. Acorn meal was also made into an unleavened bread, baked either beside the fire on a hot stone or in an earth oven similar to our fireless cooker. Red earth or ashes were sometimes added to the dough, the purpose being to neutralize any acid still remaining in the mixture. Such bread was dry enough to keep longer than the mush and also, because of its lighter weight, was commonly taken on journeys.

In northern California, western Oregon, and western Washington, the whole acorn, with or without the hull on, was buried in mud or immersed in a stream from a few weeks to a few months before eating. This eliminated most of the acid but was not as efficient as the central California method. The leached kernels were then boiled whole or roasted for eating. Boiling removed what acid may have remained after leaching, because the water was poured off and not drunk.

In a sizable area in northern California both of these leaching methods were known and used. It is significant, however, that where the acorn was a staple food, pulverizing before leaching was everywhere practiced. In western Oregon and Washington, where only the whole kernel was leached, it was not an important food. These two processes are also correlated with the frequency of oaks and hence the quantity of acorns available to the Indians. Pulverizing before leaching corresponds almost exactly to the area of greatest frequency of oaks. North of the Umpqua divide in southern Oregon, oaks are much less common (15).

There is another area, comprising roughly the northeast quarter of the United States, where the whole kernels were leached by boiling in water to which lye had been added. The lye was derived from wood ashes, and its alkaline character neutralized the tannic acid in the acorns. Species containing the most acid were boiled in several solutions of lye. After neutralizing the acid, the whole acorns were dried or roasted and stored in that condition. They were ground in a wooden mortar with a wooden pestle, a few at a time as needed, and added to boiled messes which also included meat. The wooden mortar and pestle were the same ones used to grind maize. Acorns were not much eaten in this area in historic times, except when the maize crop failed or was destroyed by enemies. However, in pre-agricultural times, before Christ, they were probably second only to wild rice as a vegetable staple. Wild game, however, was certainly a larger factor in the diet here than wild plants, and fish even outranked game in a few localities. Acorns, therefore, never attained the important place in the diet that they held in California.

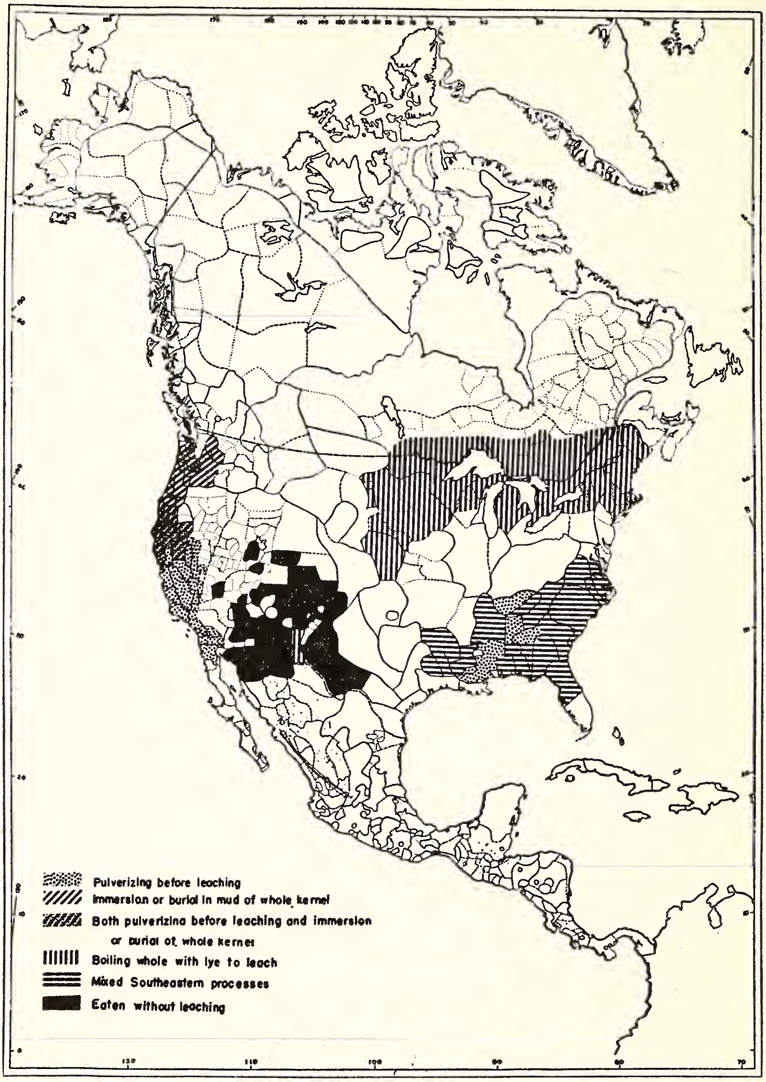
Pulverizing before leaching
Immersion or burial in mud of whole kernel
Both pulverizing before leaching and immersion or burial of whole kernel
Boiling whole with lye to leach
Mixed Southeastern processes
Eaten without leaching
120
110
100
90
80
70

Fig. 1

In the Southeastern United States, acorns were second only to hickory nuts as a source of vegetable oil. They were most often boiled whole in water and the oil skimmed from the surface. Apparently the kernels, which were automatically leached in the process, were also eaten, although this is not always reported. The majority of tribes also made some kind of acorn bread although we are not always told whether the nuts were first leached. Acorns were added to other foods, most often boiled dishes, and one gets the impression that they sometimes served as much as a condiment as a true food. Under such circumstances the tannic acid was at least diluted, if not leached out. We are rarely told specifically that acorns were leached with lye, but because lye was used in the hominy-making process it may also have been used for acorns more often than reported. Pulverizing before leaching is reported for three tribes: Choctaw, Creek, and Shawnee. Creek data on this point come from Erminie Voegelin's Twentieth Century Shawnee informants, who claim that they learned the process from the Creeks. Earlier Creek sources, which are very brief, do not mention pulverizing before leaching. Therefore we have split Creek territory arbitrarily so as to show both processes on the map. More of this leaching method below.

Acorns were eaten without true leaching in the Southwest, the southern Great Basin, and a few other isolated localities. They were eaten raw, roasted, boiled whole, or ground into a meal which was made into mush or added to other boiled dishes. Although some of these cooking techniques leached out some of the tannic acid, or at least diluted it, there was no separate leaching process. Some species are much "sweeter" (contain less acid) than others and can be eaten, at least in moderate quantities, without leaching. While figures on the tannic acid content of the various species of acorns are not available, one gets a strong impression that the vast majority of species had to be leached in some manner before they could be eaten in any quantity. Whether or not Southwestern species average less acid is unknown. However, our best source for the Western Apache states that unleached acorns were the most important single wild plant food eaten by that tribe. Wild plants furnished about a third of the total diet among Western Apache, with wild game accounting for another third, and domesticated maize the remaining third. The exact quantities of various wild plants consumed are unknown, but we will hazard a guess that unleached acorns provided 5-10 per cent of the total diet. While this figure is lower than that for central California, it is probably higher than that for any other area in North America in early historical times. In other words, it appears that the Western Apache used relatively more acorns than tribes of the Northwest, Northeast, or Southeast, in spite of the fact that they did not leach them. Other Southwestern tribes, however, made much less use of acorns.

Before we speculate on the historical relationships among the various acorn processes in North America, let us turn briefly to the Old World. Because acorns are not eaten at all from about the Canadian border north through British Columbia, Alaska, and Siberia to Japan (15), there is no indication that any kind of acorn eating or processing spread by diffusion over this route. Oaks are either absent or scarce in these northern regions, which adds to the improbability of knowledge of acorn preparation diffusing in either direction over this route. It therefore seems likely that all Old World forms of acorn preparation developed independently from those in North America.

These historical speculations differ from those of Gifford (15). He leans toward accepting a single origin for acorn eating not only for North America but for the whole world. He believes the knowledge that acorns were edible and some method of preparing them may somehow have spread by diffusion or migration across Bering Strait from one hemisphere to the other.

Most types of acorn preparation employed by North American Indians are also reported in the Old World. In Japan, acorns were boiled whole before eating. In Persia they were first pulverized, then the meal was soaked in running water for several days, and finally it was shaped into flat cakes and baked. Around the Mediterranean Sea acorns were widely eaten without leaching. However, in Sardinia they were boiled, pulverized, mixed with earth to neutralize the acid, and either eaten as mush or baked into a cake which was sometimes sprinkled with ashes before eating. Acorns have been found in the Swiss Lake dwellings, dating from about 2500 B. C., where they appear to have been eaten. Their consumption is also reported for the Pythians by Herodotus around 500 B. C. There are many other references to acorn eating in Persia and around the Mediterranean from ancient times down to the present century.

If parallel methods of acorn preparation developed independently in the Old and New Worlds, why could they not also have developed independently in North American areas? Although such speculations are never subject to final verification, we suggest that acorn eating in eastern North America may even be independent of that in western North America. While there is also a geographical gap on our map between the Northeast and Southeast, this is probably due to lack of information rather than to absence of acorn consumption in the blank area. It is therefore suggested that acorn processing in eastern North America had a single origin somewhere within the area.

Historical relations of our phenomenon in western North America are far from obvious, but diffusion of each of the three major types from a single point of origin somewhere within the area where each is found seems acceptable. Whether these three types of preparation have a common origin in some earlier period is problematical. Certainly the mere eating of unleached acorns could have arisen independently of the leaching methods.

Pulverizing before leaching occurs both in California and in the Southeast. The parallel here is more apparent than real. The Southeastern process resembled more closely that applied to hickory nuts in the same area than that used for acorns in California. For example, the Shawnee and Creek leached the acorn meal by placing it on a board and pouring warm water over it. The leached meal was then boiled and the oil skimmed off. It was not made into a mush or bread after leaching, as in California. We therefore believe that there was no historical connection between pulverizing before leaching in California and in the Southeast.

Acorn preparation apparently illustrates the operation of the principle of limited possibilities in cultural history. This has been recently stressed by Murdock (25, pp. 115, 116, 200). When there are only a limited number of solutions of a problem, the same solution tends to be arrived at independently by peoples in different parts of the world. This appears to have happened in the case of acorn preparation in the Old versus the New World and perhaps even in western versus eastern North America.

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Note. References not cited in the text were used to compile the map. The 47 references given by Gifford (15) have not been repeated. All Old World information is derived from Gifford (15).

Bibliographical Abbreviations

AAA-M	American Anthropological Association, Memoirs.
BAE-B	Bureau of American Ethnology, Bulletin.
BAE-R	Bureau of American Ethnology, Report.
PMCM-B	Public Museum of the City of Milwaukee, Bulletin.
UC-AR	University of California, Anthropological Records.
UW-PA	University of Washington, Publications in Anthropology.

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BACTERIOLOGY[1]

Chairman: R. C. BARD, Indiana University
R. L. Thompson, Indiana University Medical Center, was elected
chairman for 1953

ABSTRACTS

Lysozyme and gram positive bacteria. LOIS MYERHOLTZ and S. E. HARTSELL, Abbett Laboratories, North Chicago, and Purdue University.—The sensitivity of certain Gram positive bacteria to lysozyme and the relation of the Nakamura reaction to bacteriolysis indicates that this enzyme may act on the cell in three ways: (1) cause a change in the gram reaction and complete lysis; i.e. *M. lysodeikticus, B. subtilis var. globigii, S. lutea,* (2) cause a change in the gram reaction and partial lysis only in a certain range of the pH scale, i.e. *S. aurantiaca, M. roseus,* (3) cause no change in the gram reaction and no lysis, i.e. *M. pyogenes var. albus.*

The Nakamura reaction was essential for the observation of the effects of lysozyme on *S. aurantiaca* and *M. roseus.* No conditions have yet been found for observing a change in the gram reaction or lysis of *M. pyogenes var. albus.*

Varietal differences were noted with *B. subtilis* (insensitive) and *B. subtilis var. globigii* (sensitive).

The age of the culture was also found to influence the response to lysozyme—18 hour cultures have a greater lytic response than 24 hour cultures.

The sensitivity of *M. roseus* and *S. aurantiaca* was observed for the first time.

Effect of antibiotics on bacterial reduction of triphenyltetrazolium chloride (TTC). E. D. WEINBERG, Indiana University.—Several papers have recently appeared describing the ability of various antibacterial agents to interfere with the reduction of TTC by certain bacterial species. This phenomenon is of interest because it offers the possibility of developing a simple rapid assay method for the substances that inhibit TTC reduction, as well as the possibility of providing information concerning the selective mechanism of action of these agents.

In this laboratory, seven antibiotics were tested with resting cell suspensions of antibiotic sensitive strains of *Bacillus subtilis, Micrococcus pyogenes* var. *aureus,* and *Proteus vulgaris.* Aureomycin and terramycin consistently interfered with the ability of the cells to reduce

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[1] Joint session of the Indiana Academy, Bacteriology Division, and the Indiana Branch, Society of American Bacteriologists.

TTC. Chloramphenicol was active only in high concentrations; polymyxin, bacitracin, and streptomycin were inactive. In sharp contrast, penicillin stimulated TTC reduction.

A rapid method of assay for aureomycin and terramycin was devised. Advantages of the method include, in addition to speed, avoidance of three characteristics of overnight growth tests: need for sterility, possible deterioration of the antibiotic, and possible overgrowth of resistant variants. Disadvantages of the method include the facts that: a) the extent of TTC reduction is influenced by the kind and amount of nitrogenous and carbohydrate material present, and b) the quantity of aureomycin or terramycin required to inhibit reduction of TTC is considerably greater than that required to inhibit growth.

Evidence for the coexistence of alternate routes of carbohydrate metabolism in Penicillium chrysogenum Q-176. Edward C. Heath, Henry Koffler and E. P. Goldschmidt, Purdue University.—Preliminary studies on the breakdown of glucose by *Penicillium chrysogenum Q-176* have led to the tentative conclusion that this organism is potentially capable of utilizing both the hexosemonophosphate shunt and a mechanism (or mechanisms) by which glucose is broken into two three-carbon-fragments. Evidence in support of this contention was obtained partly with cell-free extracts prepared from alumina-ground cells, which had been grown in a synthetic medium containing glucose. Such enzyme preparations oxidized glucose-6-phosphate and 6-phosphogluconate in the presence of triphosphopyridine nucleotide (TPN), as indicated by increased absorption at 340 mμ. Apparently ribose-5-phosphate also was metabolized; pentose disappeared rapidly when ribose-5-phosphate was the substrate. Further support for the hypothesis that the hexosemonophosphate shunt exists in this organism was obtained by experiments in which the dissimilation of glucose-1-C^{14} was studied with whole cells in the presence or absence of 6×10^{-3} M arsenite. The pyruvate that accumulated in the presence of arsenite and the respiratory carbon dioxide were collected and their specific activities (cpm/μMC) determined. In the presence of arsenite the specific activities of the CO_2 and the pyruvate were six times and two-thirds the initial activity of the glucose, respectively, while in the absence of arsenite the specific activity of the CO_2 was only slightly greater than that of the initial glucose. The high radioactivity in the carbon dioxide indicates the existence of a shunt mechanism involving the preferential removal of the first carbon of glucose, while the observation that pyruvate was labeled indicates another mechanism or mechanisms by which the glucose is split into two three-carbon fragments. It is suggested that these two systems function simultaneously, at least in the presence of arsenite, but nothing is yet known about the extent to which these reactions participate in uninhibited cells.

Isolation and study of an actinophage isolated from soil. M. M. Hoehn, L. Sitler, and J. M. McGuire, Eli Lilly and Company, Indianapolis.—The actinophage designated as Lv1 was isolated from soil by an enrichment procedure using *S. venezuelae* 8-44 as the host. Plaque counts were used to measure phage titers. Ca^{++} was essential for phage multiplication in a glucose-peptone medium. Calcium concentration of 1M to 10^{-1} M gave the maximum phage count, but some multiplication occurred with only traces of Ca^{++}.

Lv1 actinophage is specific for its host *S. venezuelae* 8-44. It does not parasitize *S. rimosus*, *S. aureofaciens*, *S. griseus* No. 4, *S. griseus* No. 3463, or *S. erythreus*.

Plaque size is a distinguishing characteristic of this phage. Electron micrographs show a phage with a head and tail similar to those described in previous publications.

A statistical investigation into the factors of a starch-agar, filter-paper disc assay for amylases. RALPH WELLERSON, JR., EGON STARK, PHILIP A. TETRAULT and CARL F. KOSSACK, Purdue University.—The validity of a starch-agar, paper-disc, diffusion method for determining bacterial amylase potency has been investigated. The method consists of placing filter-discs on a starch-agar plate, applying an exact amount of enzyme solution and incubating the plates at 52° C. for six hours. The discs were removed, plates were successively flooded with an iodine solution and the zones read with a Fisher-Lilly zone reader. The optimum medium contained 1% agar and 0.2% soluble starch in M/15 Sorenson's buffer, pH 6.0. Storage of the medium at 12° C. for a week did not decrease the sensitivity of the method. A statistical analysis of the zones of hydrolysis revealed that slight differences in the concentration of starch, concentration of agar, amount of enzyme per disc, pH of the medium, temperature of incubation and the length of the incubation period introduced significantly different zone diameters. Differences in the depth of the medium and in the type and molarity of the buffer, within limits, did not affect the diameter of the zone. Reproducibility of results was very good; disc to disc, plate to plate and day to day variations having been eliminated through refinement of technique and development of a suitable testing medium. The method is simple, highly accurate and allows the simultaneous testing of a large number of samples. Since the potency of the amylase is related linearly to the diameter of the zone, an assay for bacterial, fungal, malt, pancreatic and salivary alpha amylase is being developed.

A nutritional and cytological study of a stalked bacterium from well water. E. A. GRULA and R. H. WEAVER, University of Kentucky.—Bowers (1951) was able to isolate on nutrient agar, a vibrio-shaped, gram-negative stalked bacterium from water obtained from a well in the vicinity of Sleepy Hollow, Kentucky. After rather extensive study of the organism, he suggested it to be a *Caulobacter* species. The purpose of this work has been to determine the specific vitamin and mineral requirements of the isolate of Bowers and to investigate further its cytology.

After completion of organic and mineral nutritional studies, the following chemically defined synthetic medium was found to be satisfactory for the cultivation of this organism at 30°C. $FeSO_4$, $7H_2O$, 20 mg; Riboflavin, 5μg; Dextrose, 500 mg; K_2HPO_4 and KH_2PO_4, 250 mg each; and $(NH_4)_2SO_4$, 100 mg. pH can be between 6.0 and 8.0.

Two types of intracellular inclusions were observed in this organism and labeled Body "A" and Body "B" for ease of comparison.

Because bodies of the A Type were highly dense and opaque to electron and light transmission; because they could be melted under electron bombardment; because their direct relationship to phosphates could be shown and because they stained intensely with basic dyes, it was concluded that these bodies were aggregates of inorganic phosphate (possibly hexometaphosphate) in union with acidic component, possibly RNA. As such, they may be considered to be volutin.

Since bodies of the B Type are directly influenced by iron and riboflavin levels and, to a lesser extent, phosphate concentrations, and since these chemical entities are known components of respiratory systems; because they show a high transparency to electron beams, decrease with culture age and show a strong internal turgor pressure, it is suggested that the B Type bodies in this organism are cell sap vacuoles possessing a definite membrane and showing a marked response to enzyme precursor substances. It may be further suggested that, because of this growth response to these enzyme precursor substances, bodies of the B Type possess respiratory enzymatic activity and could be the actual sites or loci of osidation and reduction in these cells.

Time Lapse Cinephotomicrography of Tissue Cultures[1] [2]

RAYMOND G. MURRAY, Indiana University

Cinephotomicrography is here interpreted to mean the recording for movie projection of objects viewed through a microscope. Time lapse recording, and the increased contrast in photographic images over that apparent by direct observation, greatly enhance the appreciation of the morphology and cytophysiology of cells growing in tissue culture. At the same time the characteristics of tissue cultures require special techniques and raise special problems in addition to those encountered in ordinary cinematography. Three principal characteristics are: (A) the small size and low contrast of the objects; (B) their slow rates of activity; (C) the complexity of simultaneously occurring processes. The problems raised by each will be briefly considered.

The small size and lack of contrast of cellular constituents, such as mitochondria and the various components of the nucleus, require the highest possible resolving power. At the histological level resolving power is not critical, for patterns of cell masses can be followed at low magnification. But when cytophysiological studies are undertaken the highest possible resolving power is needed. This means that culture chambers used for photography must be very thin to make use of condensers and objective lenses of high numerical aperture and consequent short working distance. Both sides of the culture chamber should be made of absolutely clean coverglasses, without scratches or other distorting aberrations. Curved refracting surfaces in the culture system must be avoided. Cultures which are growing in a plasma clot present a convex surface unless fluid is added to make contact between the clot and the opposite coverglass. Elimination of the air space directly adjacent to the culture may have injurious effects on the cells but many cells can tolerate such conditions for short intervals without obvious damage. A means of avoiding this has been suggested by Hughes and Fell (6), who cut an annular mote in the plasma clot just peripheral to the explant. The serum exuding from the clot filled the mote, with a flat surface across the top. Cells which subsequently grew out on the glass in the fluid of this region were selected for photography.

Phase difference optics have lately made possible a major increase in resolving power and particularly in contrast. Structures previously poorly visualized have been photographed with great clarity by this method. The techniques of phase optics, however, impose limitations in addition to those encountered in "bright field" microscopy. The absence of curved surfaces in the culture is particularly critical and extremely thin objects are the best for study. A single layer of cells, or if possible

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[2] Editor's Note. This paper and the succeeding papers in this division are part of a symposium on tissue culture studies.

isolated cells, without closely adjacent neighbors, are required for best work, and the medium in which cells are growing should be structureless (i.e., clear fluid). Thus the cells under observation may be removed from a very important environmental influence, that of closely adjacent cells. In interpreting results it must be remembered that the vast majority of cells in the culture have been excluded on an arbitrary basis. In many cases more value may be obtained from pictures taken by standard "bright field" technique rather than by phase contrast, for a greater portion of the culture may be studied by this means.

Cell processes, even in the actively amoeboid blood cells, are so slow that direct observation and analysis is an extremely tedious business. Much has been learned by direct observation, but time lapse photography makes it possible to decrease tremendously the time spent in observation. The dynamics of some cell processes cannot be clearly appreciated, and others may be entirely missed unless the time scale is sufficiently condensed that the observer can encompass the entire activity within a reasonably short time interval. More important, however, is the permanent record that can be shown repeatedly, and projected frame by frame if necessary, to analyze the activity. This becomes of major value when a number of processes are proceeding at once, as in mitotic division.

When we consider the complexity of activities proceeding simultaneously, a compromise must be made between a field taking in enough cells to record the complexity of the activity, and a resolution sufficient for the details within individual cells. It may be a matter of chance whether or not the cells in focus exhibit the hoped for activity. It is often not possible to choose the correct field by direct observation because the significance of the activity may not be apparent until the movie, with the activity speeded up, is viewed. This difficulty can be met in part by photographing with an objective of high resolving power and introducing very little further magnification. It may be profitable to replace the eye piece with a negative lens to reduce the image size. This is particularly true with the very small frames of 16 mm movie film. While 35 mm film has the advantage of permitting larger field size with the same magnification, it is much more expensive to use. As image size is reduced the grain of the film becomes the limiting factor in the resolving power of the system.

The required apparatus varies somewhat with the specific problems but should include a camera (no lens required) which has a single frame shaft, one revolution of which takes one picture, to be activated by a driving motor (not using the spring drive of the camera). The motor should be able to operate the camera continuously or to start and stop it at regular intervals, each start resulting in one picture. There must be a device between the microscope and the camera to permit focusing during photography.

A rate of exposure ranging from 2 to 120 times per minute is sufficient for nearly all situations in tissue culture. This results in a speeding up of the activity from 720 to 12 times, respectively. Activity of rapidly amoeboid blood cells can be recorded fairly well at 120 exposures per minute and it is rarely necessary to follow cells for longer than 24 hours of continuous photography. At two exposures per minute, 33 hours of activity can be recorded on 100 feet of film. The timer which starts and stops the motor and the speed of the motor are best arranged so that the exposure time is the same regardless of the interval between exposures, when operated intermittently. A convenient speed of rotation of the motor for intermittent exposure is 15 revolutions per minute or 4 seconds per revolution. Since the shutter is open about half the time of each revolution, this results in an exposure of about two seconds, which has certain advantages: it minimizes the harmfulness of slight intermittent vibrations and permits quite low intensity of light to be used. While intermittent vibration in the camera, if not too severe, can be tolerated because of the slow exposure, a vibration in the camera lasting for the entire exposure interval will, of course, result in blurred images. Any vibration of the microscope on the other hand must be avoided because of the great magnification by the lens system of any vibratory movement. For this reason camera and microscope should not be in direct contact, and the microscope should be mounted on a very solid support, insulated from sources of vibration. For continuous operation at 30, 60, and 120 times per minute, the exposure time will be proportionately shortened. The light source should also be controlled by the timer so that the culture is not illuminated between exposures.

My own apparatus consists of a synchronous motor, connected through a variable gear box to one plate of a clutch. The other side of the clutch is connected to a single frame shaft on the camera. The standard operating speed is 15 revolutions per minute but with the gear box this can be changed to 30, 60 or 120 per minute. A pin is placed to arrest the revolution of this drive shaft on the camera side of the clutch. While the pin is in place the motor continues but the clutch slips and the camera does not move. A solenoid when activated by a microswitch removes the pin momentarily, allowing the camera shaft to make one revolution. The microswitch is activated by removable pins on a disc driven at one turn per minute by a simple clock motor. The number of pins can be adjusted to give 1, 2, 4 or 8 equally spaced intervals producing a corresponding number of exposures per minute. One revolution of the camera takes 4 seconds, during about half of which the shutter is open. If the pin is continuously retracted the exposures are continuous at 15 per minute. The revolution of the camera shaft activates the light switch so that it is on during the interval when the shutter is open.

For tissues of warm blooded animals the microscope is enclosed in an incubator to maintain an even temperature. Variations in temperature must be small (0.5°) to prevent loss of focus by expansion and contraction effects.

This system has worked well except that the continuously dragging clutch puts a heavy load on the motor when exposures are being made intermittently. An excellent description of a satisfactory device has been made recently by Hughes (4) and another device is being tested at the Audio-Visual Laboratory at Indiana University, which may be superior to this one.

A large number of investigators in this country and abroad are using time lapse photography to study cells in tissue culture. The few investigations mentioned here will serve to indicate several types of problems which lend themselves to this technique.

Lewis (8) has studied a great variety of cells by this method. DeBruyn (2) analyzed the amoeboid activity of blood cells in tissue culture and showed, among other things, that variations in the type of movement were related to mechanical influences within the culture. Firor and Gey (3) have compared the activity of normal and malignant cells in tissue culture. Bloom and Zirkle (1) are investigating the effects of ionizing radiations on cells and parts of cells. It may be possible to irradiate a single chromosome or mitochondrium and note the effects. This requires a very delicate system of registration whereby the exact point irradiated can be accurately determined. Michel (9) has studied the mitotic process in spermatocytes. Hughes and Swann (7) have studied the mitotic process in certain cells using polarized light images compared on alternate frames with phase contrast images. This requires an ingenious process termed bi-frame recording and makes possible certain quantitative measurements. For example, they measured the speed of movement of chromosomes as related to the rate of change in length of the spindle. Hughes and Fell (6) and Hughes (5) have studied the effects of numerous chemical agents on cells in tissue culture. The author (10) has studied cell differentiation in tissue culture by photographing cells of a pure strain. Rapid and direct transformations of certain cells into cells of an apparently different type were seen to occur at the moment of mitotic division. The details of this phenomenon are under further investigation. Weiss (11) is engaged in photographing certain tissues infected with virus particles in the hope of following the changes that occur in the cells and in the virus colonies. The success of such photographs depends in part, in this case, on the fact that the particular virus he is using (feline pneumonitis virus) is large enough to be resolved by phase contrast optical systems.

In conclusion, the method of time lapse cinephotomicrography can give information about certain problems which is not available by other means, with apparatus which is not too expensive or difficult to operate. Interpretation of results, however, must take account of certain important reservations: (A) results may be significantly influenced by choice of cells to be photographed; (B) added to the already numerous unknown factors affecting cells in vitro are additional unknown effects peculiar to the conditions of light, mechanics and nutrition under which time lapse cinephotomicrographs are made.

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The Development and Role of p-Aminobenzoic Acid in the Early Chick Embryo[1]

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Morphogenesis, cellular differentiation and growth are the result of an ordered sequence of physical and chemical transformations. Contrary to older opinion, the complement of proteins and conjugated proteins of the early embryo (e.g., the chick embryo at the definitive primitive streak stage) is comprehensive and highly complex, as revealed by immunochemical and enzymatic analyses (10, 16). In the course of further development, the protein complement of the embryo undergoes a progressive change resulting from the operation of at least three distinct processes, viz., (1) structural transformations of proteins; (2) purely quantitative changes in the number of protein molecules; and (3) qualitative changes in the kinds of proteins. At the outset of the discussion, care must be taken to emphasize that mechanisms two and three may be subtractive as well as additive. For example, many enzymes are more active in early than in later stages of development. To cite a case in point, Levy and Palmer (14) have convincingly shown that during the first few days of development embryonic tissue becomes poorer, not richer, in aminopeptidase. Moreover, although certain tissue-specific antigens are added during the course of development, other, transitory, antigens disappear (9, 10). The present investigation is directed toward an understanding of one link in the chain of metabolic processes underlying protein synthesis in the early chick embryo. The conjugated protein, hemoglobin, has been selected for analysis, for the following reasons: (1) relatively early appearance during development (blood islands are present in the posterior half of the blastoderm at the four somite stage), and (2) striking visual criteria of identification (appearance of characteristic red color and specific staining with patent blue [7]). Moreover, considerable information is available on the nature of hemoglobin in vertebrate embryos, young animals, and adults. Embryonic hemoglobin has been shown to be different from that of the adult, for they behave as different antigens (6), have different solubilities (29), sedimentation constants and electrophoretic mobilities (1) and osmotic pressures (15). While investigators generally agree that it is the globin moiety which differs in the embryo from the adult, Riggs (18) has recently proposed that the difference may be due to a change in the mode of linkage between the heme and globin components. In addition there is considerable information (largely mutually corroborative) in regard to the time course of accumulation of hemoglobin in the embryo (17). There is, however, a dearth of information concerning the factors controlling its synthesis.

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[2] This investigation was initiated at The Johns Hopkins University in collaboration with Irwin R. Konigsberg, whose stimulating contributions to the inception of the work are gratefully acknowledged.

The approach to the problem adopted in the present investigation was suggested by Needham (17) as early as 1942. Following a lucid discussion of the history of liver therapy in macrocytic anemias, he reviewed the evidence presented by Wintrobe and Shumacker (25) which suggested that the hematopoietic tissues of the embryo are influenced by the anti-anemia factor of liver extracts. Knowledge of the chemistry of the liver anti-anemia principle was meagre at that time. Yet from a review of the available information, particularly that concerning the occurrence of pterines (complex purines) in the liver extracts, and from a consideration of the known functions of the purines, Needham suggested that the probable role of the pterines might be in the formation of the active anti-anemia principle. He concluded (p. 650), "in the light of all these facts, it is clear that the pterine metabolism of developing embryos in full hematopoiesis urgently invites study."

Despite the early statement of the problem, suitable methods for its attack have been developed only recently, through advances in two fields, namely: (1) The demonstration by Spratt (20-22) that one may gain insight into the control mechanisms which characterize the processes of differentiation and morphogenesis by an examination of the nutritional requirements of blastoderms in progressive stages of development, *in vitro;* and (2) the application of antimetabolites has provided a keen tool for the study of biochemical processes, particularly in studies of biosynthesis. A combined approach to the problem of the role of nutritional factors in the synthesis of hemoglobin is, therefore, available. The specific factors to be considered here are folic acid (folacin, pteroylglutamic acid, PGA) and its integral structural moiety, p-aminobenzoic acid (PABA).

The Folic Acid—p-Aminobenzoic Acid Relationship

That folic acid (or its conjugates or derivatives) is intimately involved in erythropoiesis has been demonstrated convincingly in both clinical and experimental studies. Remission of symptoms involving hematopoietic failure in certain members of the "family" of macrocytic anemias is regularly obtained by administration of folic acid (neurologic lesions are alleviated only by administration of vitamin B-12; the exact relationship between folic acid and vitamin B-12 has not been elucidated). Shive (19) has summarized the evidence that folic acid (probably as folinic acid or a coenzyme form of it) functions in the synthesis of purines and the pyrimidine, thymine. At the time that the structure and synthesis of folic acid were announced, the antimetabolite concept was well established. The synthesis of folic acid was followed by the synthesis of a large number of related compounds for study as antimetabolites. Structural analogues of PABA also are available; in fact, the classical analysis of the PABA-sulfonamide relationship by Woods and Fildes (26) first led to the realization that compounds structurally similar to metabolites have broad application in chemotherapy and related fields and prompted a widespread search for inhibitory analogues of metabolites. Further emphasis of the importance of PABA came with the proof of its presence in the folic acid molecule. PABA is undoubtedly a precursor of folic acid. Woolley (27) has, in fact, proposed that sulfonamide effectiveness is due primarily to interference with folic acid synthesis. On the other hand, the excellent series of inhibition analyses by Shive and his collaborators clearly shows that PABA is involved not only in the synthesis of folic acid, purines and thymine, but of methionine and serine as well. The interrelationships of PGA and PABA cannot be fully interpreted on the basis of present knowledge. Shive has advanced two possible explanations of their relationship: (1) a single coenzyme may be formed from PABA and PGA, and the organisms which utilize PABA for the formation of the coenzyme may differ in their ability to convert PGA to the coenzyme. Folic acid may then be utilized only slowly by an organism which utilizes PABA rapidly. (2) The alternative view would be that more than one coenzyme is formed. If such is the case, organisms utilizing folic acid must have the ability to convert folic acid to these coenzymes by processes not affected by sulfonamides.

The Effects of Sulfonamides on the Development, in vitro, of the Early Chick Blastoderm

Copenhaver and Detwiler (4), have reported the results of an investigation of the effects of sulfonamides on the development of *Amblystoma punctatum*. Embryos were reared in solutions of sulfadiazine (0.12 to 2.0 per cent) and sulfanilamide (0.25 to 1.0 per cent). Embryos were placed in the solutions at the following stages (Harrison): 8, 12, 25 and 28. Embryos at the earlier stages rarely survived to the stage of yolk resorption when reared in the 2 per cent sulfadiazine solution. When embryos were reared in either inhibitor in concentrations of 1 per cent, or less, there were few toxic effects in the early stages. In embryos reared until late stages (40 to 46) there were pathological changes resembling those reported from the application of sulfonamides in clinical usage (23), among the most frequent being anemia. Bass, Yntema, and Hammond (2) have described briefly the effects of sulfonamides on the development of the mouse and chick embryos. No details are given, but in the latter case it was stated that "the drug appeared to interfere with the development of the vascular system." These results suggest that the sulfonamides, generally believed to distinguish bacterial metabolism from that of vertebrate tissues, are, in fact, effective antimetabolites in embryonic metabolism. It follows, therefore, that PABA is an essential metabolite during embryonic development. The findings of the present analysis support this view.

The dependence of the developmental processes upon an appropriate supply of exogenous nutrients provides the opportunity to isolate and cultivate the embryo, in vitro, in a suitable nutrient environment containing antimetabolites, both in the presence and absence of the specific metabolites under consideration. At the outset of the experiments described below, early chick blastoderms were cultivated on either (1) a medium composed of saline-agar + albumen extract, or (2) a chemically defined complete (synthetic) medium. Directions for preparation of the media and complete operative procedures have been described in earlier reports (8, 20). Both of the media tested in the preliminary experiments were adequate for the initiation and continuation of morphogenesis and differentiation of the early blastoderm. Only the albumen extract medium supported hemoglobin formation consistently, however; thus it was the medium employed in all the experiments to be described.

In all tests employing antimetabolites, a measured amount of a sterilized stock solution of the inhibitor was added to the medium after it had cooled to 40-45° C. The pH of the medium was measured with the Beckman pHmeter at the beginning and end of each experiment, and was found to remain relatively constant (8.3-8.5). In the experiments in which the extent of protection against the analogue by added vitamin was determined, a measured amount of a sterilized stock solution of the vitamin was added together with the inhibitor. A total of 324 chick blastoderms (stages 4 to 8 of the Hamburger-Hamilton series [11]) was explanted to the control medium and to media containing sulfanilamide, either alone or in combination with one of the growth factors; an additional 42 embryos were cultured in media to which one of the growth factors alone was added. The results are summarized in table 1. (Another group of 30 blastoderms was cultured in media containing sodium sulfadiazine; these data are not included in the tables.)

TABLE I

Development on media containing sulfanilamide with or without added vitamins

details in text

Medium Saline-Agar + Albumen Extract	No. of Blastoderms Explanted	Stage of Blastoderms Explanted	Survival	Growth	Hemoglobin formation after		
					20	40	60 hours in vitro
alone	30	4-5	29	+	—	+	+
alone	33	6-8	31	+	+	+	+
+ sulfanilamide 10-50 micrograms/ml.	47	4-8	0				
+ sulfanilamide 10-50 micrograms/ml.	51	6-8	46	retarded	—	—	—
+ sulfanilamide over 50 micrograms/ml.	39	6-8	25	greatly retarded	—	—	—
+ PABA/sulfanilamide 1/100-1/2500	34	4-5	0				
+ PABA/sulfanilamide 1/100-1/2500	37	6-8	35	retarded	+	+	+
PABA alone 10-100 micrograms/ml.	19	4-8	19	+	+	+	+
+ PGA/sulfanilamide 1/10-1/200	31	4-5	0				
+ PGA/sulfanilamide 1/10-1/200	22	6-8	22	retarded	+	+	+
+ PGA alone 10-250 micrograms/ml.	23	4-8	21	+	+	+	+

The effects produced by the antimetabolite are related directly to the stage of development at the time of explantation. Let us consider first the effects of sulfanilamide on embryos explanted at stages 4 and 5 (definitive primitive streak and head process blastoderms). Even the lowest concentration of sulfanilamide indicated in table 1, 10 micrograms per milliliter of medium, completely blocks the development of the embryo. Within an hour after explantation, the embryos were opaque; the condition persisted for as long as 10 hours before degenerative changes were observed. In addition to the inhibition of morphogenetic and differentiative mechanisms, growth was completely inhibited. Seventeen additional embryos explanted to media containing sulfanilamide in a final concentration of 5 micrograms per milliliter underwent essentially normal morphogenesis and differentiation, but exhibited the generalized retardation of growth. The complete inhibition of growth and development produced by sulfanilamide resembles the marked effect obtained when media are purposely made toxic in various ways (too high an osmotic pressure, etc.) (20). That the sulfanilamide inhibition at these stages is, indeed, of a general nature, probably not due to a specific antimetabolic effect of the inhibitor, is further indicated by the fact that the inhibition is not prevented by either PABA or PGA, in final vitamin: inhibitor ratios as high as 1:100 and 1:10 respectively, ratios far greater than those required to prevent inhibition in all other organisms studied.

The findings at stages 6 to 8 differ sharply from the foregoing. Concentrations of sulfanilamide between 10 and 50 gammas produce a relatively specific effect on the embryo, viz., an inhibition of hemoglobin formation. The morphogenesis and differentiation of the embryo are relatively normal; the nervous system is well organized, a pulsating heart develops. Yet hemoglobin is not formed; embryos were observed routinely at 20, 40 and 60 hours after explantation, and in some instances at 100 hours after explantation. In addition to the specific effect of the inhibitor, growth was retarded. Concentrations of sulfanilamide above 50 gammas (120 gammas per milliliter being the highest concentration tested), while affecting hemoglobin synthesis, also inhibit morphogenesis and differentiation. Of the 25 embryos which survived the higher concentrations of the inhibitor, 21 exhibited gross structural abnormalities, including the failure of the mesoderm to differentiate into clearly demarcated somites. Growth was completely retarded, dwarf embryos being produced. The findings further show that the effect on hemoglobin synthesis is a direct result of the antimetabolic function of sulfanilamide. The inhibition of hemoglobin production at stages 6 to 8 is readily prevented by the addition of either PABA or PGA to the medium, at vitamin/sulfanilamide ratios as low as 1/2500 and 1/200 respectively. Only the effect on hemoglobin formation is prevented by the vitamins, however; the generalized retardation of growth is not prevented.

From the foregoing discussion, the following tentative conclusions may be derived: (1) the complete inhibition of all developmental activity obtained with sulfanilamide at stages 4 and 5, and the generalized growth retardation observed at stages 6 to 8 are apparently not related to the usual antimetabolic role of sulfanilamide, since the inhibition cannot be prevented with either PABA or PGA. The results of other, preliminary,

TABLE II

p-Aminobenzoic acid in the early chick embryo.

Sample: Blastoderms at	No. of Embryos	Weight of Sample in milligrams	PABA in Sample in micrograms	PABA/mg. of dry weight in micrograms
Stage 4	65	2.3	.0031	.0013
4	64	2.7	.0039	.0014
6	59	3.1	.0049	.0016
6	59	3.3	.0047	.0014
8	51	3.8	.0060	.0016
8	50	4.3	.0056	.0013
YOLK	—	6.1	.0067	.0011
YOLK	—	6.2	.0063	.0010
ALBUMEN	—	6.0	.0030	.0005
ALBUMEN	—	6.3	.0027	.0004

experiments further indicate that these effects are not prevented by added methionine. Serine has not been tested. (2) The relatively specific inhibition of hemoglobin production at stages 6 to 8 is due to the specific antimetabolic role of sulfanilamide. Sulfanilamide is, in effect, blocking folic acid synthesis, which consequently results in the failure of the embryo to produce hemoglobin. The inhibition is prevented by either PABA or PGA, as expected. The results lead to a further question. Since sulfanilamide becomes effective as an antimetabolite only after stage 5, it would appear that either (1) PABA is not present in the embryo prior to stage 6 or (2) PABA may be present but has no role, i.e. that it becomes functional only at stage 6 and thereafter. It is possible to answer the question in favor of the second alternative as a result of the experiments to be discussed below.

p-Aminobenzoic Acid Concentration in the Early Embryo

The concentration of PABA in the early chick embryo at progressive stages of development was determined by a standard microbiological assay technique. The microbiological assay method of Landy and Dicken (13), as modified by Cheldelin and Bennett (3) proved to be sufficiently sensitive and hence was adopted. The test organism was *Acetobacter suboxydans* (ATTC 621). The technique was used exactly as described by its authors; hence details of procedure need not be stated here. Following determination of the standard curve the following samples were assayed: embryos at stages 4, 6, 8, fresh yolk, fresh albumen. Embryos were rapidly removed from the yolk in the usual manner, carefully trimmed of all adhering yolk, washed in three changes of sterile chick Ringer's solution, drained, and dried over calcium chloride, *in vacuo*, for 36 hours at 4° C. The samples were weighed rapidly on an analytical balance, ground in a Ten Brock glass tissue grinder in 2 ml. of glass distilled water, and autoclaved for 30 minutes at 120° C., 15 pounds pressure. The extract was centrifuged at 3600 r.p.m. for 30 minutes; the centrifugate was discarded. The supernatant was diluted to 5 ml. with glass distilled water and added to the standard assay medium. Following inoculation from a washed 24-hour culture, the flasks were incubated at 30° C. for 48 hours. After that time the flasks were shaken and the optical density read directly in the Coleman spectrophotometer at 540 millimicrons. The quantity of the vitamin in the sample was determined by comparison with the standard curve. The results of the determinations, in which a total of 348 embryos was assayed, are given in table 2.

Clearly, PABA is present in the blastoderm as early as stage 4, and remains relatively constant in amount per milligram of dry weight through stage 8. It follows, therefore, that PABA has no essential role in folic acid synthesis until the beginning of stage 6. The nature of the generalized growth retardation which cannot be prevented by PABA administration remains unanswered. Zwilling and DeBell (30) have reported that injections of sulfanilamide into the yolk sac of developing embryos (as early as 30 hours) produce micromelia, parrot-beak and growth retardation. PABA did not prevent the effects of sulfanilamide. In fact it exaggerated the condition. On the latter point, the present findings are not in agreement. It is probable that the discrepancy may be explained by the difference in concentration of PABA employed. The smallest amount administered by Zwilling and DeBell was reported as 5 mg., 50 times greater than the highest concentration reported here.

Other lines of evidence indicate that folic acid is essential for embryonic development. The studies of Karnofsky, Patterson, and Ridgway (12) and Cravens (5), for example, have shown that high concentrations of the folic acid analogue, aminopterin (4 amino folic acid), injected into the egg cause mortality in the developing chick, resulting from a profound inhibition of growth and of hemoglobin formation. Wagley and Morgan (24) have reported that aminopterin similarly injected, causes marked changes in the yolk sac blood islets, as revealed by cytological studies. In each case, the inhibition is not prevented by folic acid, but is prevented by folinic acid, indicating that aminopterin functions by interfering with the conversion of folic acid to folinic acid. The results of nutritional experiments with breeding hens also support the view that folic acid is essential for development. Feeding the hen a diet low in PGA results in a marked reduction in hatchability, due to 2 peaks of mortality, one during the first week of incubation, the other just prior to hatching. The injection of PGA into deficient eggs prior to the fourth day of incubation permits normal development (5).

The evidence obtained from analyses of the effects of folic acid analogues lends support to the idea presented here, i.e. that sulfanilamide inhibition of hemoglobin formation is achieved through interference with folic acid synthesis. On the other hand the growth retardation obtained with sulfanilamide apparently does not involve the same mechanism as does the growth retardation achieved with aminopterin. The latter effect can be prevented by folinic acid or by purines and the pyrimidine, thymine. Since the purines and pyrimidines are precursors of nucleic acids, it has been concluded that aminopterin inhibition of growth is due to a failure of nucleic acid sylthesis (28). The sulfanilamide inhibition of growth cannot be prevented, however, with the corresponding metabolites. Although it would be unwise to state that the mechanism of sulfanilamide inhibition of growth clearly does not involve an inhibition of nucleic acid synthesis, the evidence does indicate that another pathway is more likely involved.

Summary

Evidence is presented that p-aminobenzoic acid (PABA) is present in the chick embryo as early as the definitive primitive streak stage, and remains relatively constant in amount per milligram of dry weight through the early somite stages. The results further indicate, however, that PABA may have no essential role in the metabolism of hemoglobin formation until the head fold stage, for it is only at that time that it is first possible to reversibly inhibit hemoglobin synthesis with sulfanilamide (SAN). Inhibition during this period is prevented by both PABA and folic acid; complete reversal is obtained with PABA at a PABA/SAN ratio of 1/2500; reversal with folic acid is achieved only with large quantities of the vitmain (index 1/200). Inhibition of development prior to the head fold stage, and growth retardation at all stages cannot be reversed with either PABA or folic acid.

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Applications of Plant Tissue Culture

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The history and, in turn, the applications of plant tissue culture have differed from those of animal tissue cultures as a consequence of three fundamental differences in origin and organization between the tissues of higher plants and higher animals. Of these, the first—and most important in comprehending what is to follow—is that plant organs develop from meristems, i.e., from organized clusters of dividing cells. These may be terminal, situated at the extremities of developing organs, or lateral, in the form of cylindrical sheets of dividing tissue enclosing a central core of derivatives and in turn enclosed by a hollow cylinder of outward derivatives. Cell divisions in other parts of the plant are rare and usually occur only in response to injury.

The second important difference lies in the encasement of plant cells in rigid cellulose walls. These walls are plastic and can be changed in shape and size by growth processes, but effectively prevent any motility. Consequently plant tissues in culture do not exhibit the appearance of a spreading colony, but produce instead either complete organs or mounded growths. Each cell is cemented in the position in which it formed, except as it is displaced by division or enlargement of adjacent cells.

Finally, plant cells are not typically bathed in any tissue fluid like the animal lymph. In fact, most plant juices are definitely detrimental to tissues in culture, and while it has been possible to obtain useful fractions from some of these extracts, it has not been possible to culture plant parts on the vegetable counterparts of plasma clots and embryo extracts. Consequently it was necessary with plant tissue cultures to develop synthetic media, and this had to wait for further development of our knowledge of compounds involved in growth.

So, although the first real attempts at plant tissue culture date back to Haberlandt in 1902 (8), the period that followed was marked by little real progress. With few exceptions, investigators would publish one or two papers describing negative results, then turn to more productive researches. There did develop during this period, however, the gradual realization that mature or differentiated tissues offered little promise, whereas the organized meristems would develop for a short time at least. This realization, together with the unfolding of the bios story in the '30's, made it possible for several investigators almost simultaneously in 1934 to publish reports of successful culture of plant tissue. P. R. White (16) in this country was first to obtain unlimited growth of tomato roots while Gautheret (3) in France obtained extensive development of fragments of cambium.

This development led naturally to the first of the applications of plant tissue cultures of which I wish to speak—to the study of the heterotrophic nutrition of autotrophic plants. Green plants, of course, are nutritionally independent of other living organisms. Since they can synthesize all their requirements from inorganic materials and the sun's energy, they are the fundamental source of food for all living organisms.

Yet even within the plant, the manufacture of food is confined to limited regions, usually the leaves. The rest of the plant—the stem tissues, the roots, and all of the meristems—are incapable of manufacturing food and are just as dependent on photosynthesizing tissues as are the animals. With the plant intact, there is no way of determining the essentiality of the materials exchanged between the leaf and the non-green parts. The success of the first tissue culture opened the way for the study of the nutrition of separate plant organs—a study that is by no means completed.

In general, the isolated parts require an energy source and certain growth factors as organic supplements to the media. Rather surprisingly, sucrose has proved superior to other sugars for the majority of tissues. In tomato roots, however, only one-fourth of the sucrose provided is actually utilized in growth, the remainder appearing in the medium as hexoses. Phosphate must be available for sucrose utilization and the process is inhibited by phloridzin (15). This and other evidence indicates that sugar is absorbed as hexose-phosphate formed at the cell surface from sucrose by a phosphorylase. This is quite different from the absorption mediated by hexokinase in mammalian kidney and intestine and raises the question of how and where the abundant free glucose and fructose of plant tissues is utilized.

Among the growth substances, thiamine is quite generally required. Pyridoxine and niacin are beneficial for some roots but not for others. Biotin and pantothenic acid must be supplied for willow cambium (7), but carrot cambium succeeds without either of these. Coconut milk provides for certain embryos and callus cultures factors which have not yet been identified. Beyond this there are numerous tissues and organs which cannot be cultured on present media and which must require other nutrients. It is of particular interest that no one has yet demonstrated in plants a requirement for any of the fat-soluble compounds required for growth or full development of mammals and birds.

From all of this there emerges *no* clear evidence that there exists a special nutrition of roots that differs consistently from the nutrition of stems, or of the cambium, or of any other part. The various requirements of the heterotrophic portions of the plant seem to be rather random losses of synthetic abilities which are unnecessary and extravagant in view of the greater synthetic capacities of the photosynthetic tissues. The heterotrophic portions of plants depend on their normal environment in much the same fashion that the ubiquitous saprophytic bacteria and molds depend on theirs. This does not mean that the relative growth of different parts of the plant cannot be regulated by materials exchanged between the parts. The exchange, however, seems to control the amount of growth, rather than the nature of the growth.

Synthetic abilities are often more precisely allocated to specific organs or tissues. One example of this, which was demonstrated with the help of tissue culture, is the restriction of nicotine synthesis to the roots of the tobacco plant. Cultured roots continue to form nicotine and excrete it into the culture fluid (2).

While there are no specific requirements for the *maintenance* of particular patterns of development, there are rather precise requirements for the *initiation* of new patterns. This takes us into the area of morphogenesis—to which plant tissue culture has perhaps made its greatest contribution. The first—and a major—contribution was already at hand with the achievement of successful root cultures. The demonstration that a small portion, 1mm. or less, of the root tip could be separated from the remainder of the plant and would continue to produce normal root (12) served to establish that the whole of the organizational requirement for root was contained in this small region. No morphogenetic field extends from other parts of the plant or even from older portions of the same root. The developmental pattern is inherent in the organization of the root meristem itself. This restriction of the morphogenetic field occurs also in stem meristems (10) and in very young fruits (11).

Cambium cultures may be an exception. These meristems, when placed in culture, demonstrate their original polarity by producing cells characteristic of wood on one side of the dividing layer and quite differently specialized cells on the other. Some morphogenetic influence is lacking, however, for the specialized derivatives lack their original orientation. With continued culture the plate-like structure of the meristem disappears and is replaced by isolated clusters of dividing cells which produce unspecialized derivatives (6). Here it seems apparent that cambium is dependent for its continued development as cambium on physical or chemical influences from the tissues which normally surround it. The morphogenetic field must be more diffuse than in the case of the root meristem, hence essential components of the field can be, and are, left behind when the tissue is extirpated.

Some small progress has been made toward an elucidation of the components of such morphogenetic fields in a few cases. White in 1939 (17) made the important observation that cultures of tobacco callus, which display no differentiation of organized tissues when cultivated on the surface of agar media, would produce well-organized stem tips if submerged in liquid. Subsequently Skoog and Tsui (14) demonstrated that the frequency of stem meristem formation could be markedly increased by incorporation into the medium of critical concentrations of adenine. If we add to this the assumption, which is probably justified by analogy with other stems, that tobacco stem tips do not require added adenine for their continued growth, we have here two components of a field capable of organizing a complex meristem from a relatively undifferentiated, but proliferating, tissue mass. The first component is probably physical-chemical in nature, perhaps a gradient in oxygen availability; the other is a specific chemical compound.

In contrast to the effect of adenine, auxin, the plant growth hormone, will induce the formation of root initials by undifferentiated callus cultures of various sorts (4). Roots of the same species are capable of unlimited growth in the absence of auxin. It is the initiation of the meristem that requires specific conditions.

This chemical regulator, auxin, deserves further attention here. It is probably the most versatile hormone known. It is produced, or at least activated, in plant meristems, thence it is transported to other portions of the plant where it induces morphogenetic responses. To mention a few of these, it has been associated with the elongation of cells, the inhibition of bud growth, the initiation of cambial activity, the initiation of root primordia, the suppression of root growth, and the induction or suppression of flowering. The particular nature of the response induced depends on the concentration of the hormone at the site of response and on the competence of the exposed tissue.

In plant tissue cultures, auxin has been of special importance because certain tissues which fail to proliferate in usual nutrients will proliferate rapidly if critical concentrations of auxin are included in the medium. This observation was made first by Gautheret with cultures of carrot cambium (4). At first, auxin was considered to have a nutrient role, although it was recognized that the concentration was extremely critical and that excesses led to formative effects in the tissue. Later, it was established that tissues which had been grown in media containing auxin could be transferred to auxin-free media where they would continue their proliferation at an undiminished rate (5). This phenomenon has been called "habituation." Subsequent analyses have shown that the habituated tissues produce their own auxin. Hence it seems that auxin induces its own formation in at least a portion of the tissues exposed to it.

Auxin induces another self-sustaining response in cultures of sunflower roots. Roots grown in liquid media containing auxin are shorter, more transparent, and more irregular in outline than roots of the same clone grown without auxin. Such auxin-treated roots will continue the modified pattern when subsequently cultured in auxin-free media (9).

Now I wish to turn to the field of plant pathology where there are many instances in which a parasite by means of its activities and its secretions induces a divergence from the typical growth pattern of its host. The growths which develop upon such stimulation have been called galls, but some have been likened, quite justifiably, to cancers. One in particular, crown gall caused by a bacterium, *Phytomonas tumefaciens*, has lent itself to investigation by the tissue culture technique. Infection of a susceptible host results in irregular tumorous outgrowths of the stem accompanied by secondary outgrowths of the stem or leaves above the primary infection. Braun in 1941 (1) demonstrated that secondary tumors in sunflowers were frequently free of bacteria and he and White in the same year (18) found that tissues of these secondary galls would proliferate rapidly in culture whereas normal stem tissues would not. When cultured tissue was grafted into healthy plants, tumors resulted. Quite obviously the activities of the bacteria had produced a sustained alteration in the growth proclivities of the tissue. Subsequently it has been demonstrated that the bacteria-free gall tissue can itself induce normal stem tissue to proliferate, provided it is united to the normal tissue by a completed graft union (13). Extracts of bacteria or of galls do not have this ability.

Apparently the bacteria exerts on the host tissues, and gall tissues on normal tissues, an influence that is similar to the habituation to auxin that was observed by Gautheret. Auxin itself, however, fails to induce proliferation of certain stem tissues that respond readily to the bacteria. In cases where habituated and crown gall tissues from the same plant could be compared, the cultures differ in growth rate, in morphological characters, and in auxin content.

From these various experiments, performed with different original objectives, there are two conclusions to be derived which seem to me of general importance in comprehending plant development. In the first place, while the nutritional requirements of individual meristems may vary, there does not seem to be a nutrition characteristic of particular classes of meristems such as roots, stems, or cambia. Secondly, there are many cases in which a particular pattern of development requires special conditions for its initiation which are not required for its maintenance.

It appears, therefore, that the property of inducing a direction of development which is subsequently self-sustaining is not a restricted phenomenon in plants. In fact, meristems, once organized, are essentially in steady states of varying degrees of stability.[1] The critical points in plant development seem to lie in the organization of new patterns compatible with the genetical and physiological capacities of the cells.

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[1] It is necessary, however, to recognize also the existence of progressive states which lead through a sequence of stages of the production of determinate structures. Meristems of this sort are represented by the leaf initial and the flower primordium.

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Newer Methods and Practical Applications of Tissue Culture

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The question of whether tissue culture is an art, a technique or a science has been debated, and like so many similar controversies this argument revolves around one's own definition of terms. If, however, one thinks of a science as study based on well established underlying principles, the conventional methods of tissue culture are found to be somewhat lacking in these fundamentals. Much of tissue culture work, including some of the newer procedures which are to be discussed at this time, is conducted by empirical methods and rule of the thumb laws, but it is felt, however, that steps in the right direction are being made. It is not intended to discredit anyone or any procedure, for much information has been gained through the years by investigators in various fields of biological science who have employed an assortment of tissue culture techniques. It is intended, however, to point out the limitations of the customary plasma clot culture method and to discuss some of the advances that have been made in order to overcome these inadequacies of the conventional method.

Some of the more serious shortcomings of the plasma clot culture are physical in nature, which include (1) the restriction on size of cultures, (2) the excessive time involved in preparing and maintaining cultures, (3) the fact that the cells cannot be removed entirely from the clot in the form of a suspension permitting accurate quantitative studies, (4) the handicap to visual observation and differentiations, and (5) the distortion of cell morphology. An equally serious objection to the plasma clot is recognized from the chemical standpoint because it tremendously complicates metabolical or nutritional studies.

Numerous investigators have struggled with the problem of improving and increasing the applications of tissue cultures through the elimination of the plasma clot. Some have done this by substituting simpler materials, others by attempts to free the cells from the clot. Outstanding among such investigators have been Earle and his associates at the National Cancer Institute. These workers first were able to dispose of the plasma clot by replacing it with a substrate of perforated cellophane (1) which allowed the cells to cover a much greater area, and in a uniform pattern rather than spreading out from a small clump of cells in the center of the flask. Of even greater significance, it was possible to scrape, or shake, these cells loose from the cellophane and pipette them as a suspension to new flasks, thus establishing serial cultures. Such cultures are maintained very much like those of the bacteriologist. These cultures, in which all the cells can be removed as a suspension, have greatly increased the possibilities for true quantitative handling of cell structures as this has been realized through the development of a method for planting replicate cultures (2) and for the enumeration of nuclei as an index of cell proliferation (3). It has further been possible in several instances to isolate a single cell from these cultures and to initiate a clone from it, thereby yielding the first unequivocably pure cell cultures (4, 5).

Evans and Earle's (1) use of perforated cellophane as a substitute for the plasma clot has worked admirably well for certain cell types, especially embryonic connective tissue elements, but unfortunately has remained inferior to the plasma clot as a substrate for initiating cultures of more specialized cells from either embryonic or adult tissues. They have, however, found that some of these cells, which are more difficult to handle, can be induced to grow on cellophane if it is embedded in a plasma clot and the cells exposed to it while growing on the more favorable plasma substrate. Subcultures can sometimes be made then to other flasks having only a cellophane substrate. By these methods Earle's group has established several lines of connective tissue cells, notably among them Strain L (6), and a mouse liver culture. Strain L is at present twelve years old, while the liver cells have now been carried in serial culture for approximately five years. After these cultures had been carried for a while on cellophane it was found that they could be adapted to growth directly on the glass floor of the flask and thereby the cellophane was also eliminated.

Another technique for establishing and maintaining cell cultures directly on glass has been developed in our laboratory and has, to date, supplied us with six lines of cells (7). Plasma clot roller tube cultures were used for the original explants, but were slightly modified as only a thin line of plasma, about one-fourth inch wide, was streaked down one side of the tube in place of the customary coating of the entire inner surface. The explants were seated in this strip of plasma, which was clotted by a drop of chick embryo extract, and by forty-eight hours, a zone of outgrowth could be seen in the plasma clot around the explants. As growth continued, however, the cells came out of the thin line of plasma onto the glass surface and by two to three months had completely covered the entire lower portion of the tube. Thus, a dense population of cells growing directly on glass and free of plasma had been obtained. The area of growth in each roller tube covered at least 3000 sq. mm. When the cells in this area were scraped loose and transferred to a Carrel D 3.5 flask with a floor area of 948.6 sq. mm., a three-fold increase in population density was obtained which favored survival and continued growth of the transplanted cells. The first attempt to subculture cells by this scraping and pipetting method is the most crucial step in the procedure as more experiments fail at this point than any other. Following sufficient proliferation in the first D 3.5 flask subcultures, the cells have been scraped loose and transferred to the larger Carrel D 5.0 flasks and from these were carried over eventually to the large T-60 (60 sq. cm.) flask of Earle's in which they are being maintained as stock cultures.

Four of the six strains of cells were established in our laboratory by this procedure. Included in these are two malignant ones, the mouse sarcoma 180 and the Walker rat carcinoma 256, and two apparently different cell types grown from normal embryonic mouse skin.

The remaining two cell strains were obtained by slightly different procedures. A very proliferative strain or normal adult mouse connective tissue cells was obtained by scraping the cells loose from an area on a Carrel flask where the glass had been exposed by lysis of the clot and pipetting them to a similar vessel devoid of plasma. These cells have been maintained in serial culture now for over a year, still are in a state of rapid proliferation and are apparently quite healthy. This culture will be identified in the literature as LLC-M1.

The sixth line of cells being carried in our laboratory was started from the Ehrlich ascites tumor cells of mice. This culture, now in its ninth month of existence, was started by pipetting the cells, which can be removed from the animal in the form of a suspension, directly to the glass surface of Carrel D 3.5 flasks. Growth in, or on a plasma clot, on cellophane, or in roller tubes has not occurred.

The advantages of working with these large glass substrate cultures are many, both from the standpoint of facility and from experimental competency. By maintaining stocks of each cell strain in the large T-60 flasks, as many as thirty Carrel D 3.5 or T-12 flasks can be uniformly inoculated with a cell suspension prepared by scraping the T-60 flask. Furthermore, if so planted, these thirty subcultures will be both quantitative and qualitative replicate cultures, and it can be expected that all thirty will be usable, at least to the same degree of reliance as is anticipated in dealing with bacterial cultures. This entire procedure can be accomplished in a matter of about twenty minutes, in contrast to more than one or two hours required to put on thirty plasma clot cultures. Of the latter there is very little assurance that all thirty cultures will grow, in fact few investigators would expect it. Then, too, there is frequently a considerable difference in the amount of growth in each primary culture as well as the possibility of having several different cell types present in the same or in sister cultures. This could and does have considerable effect on the comparison of results obtained from such cultures. A further advantage of serial tissue culture is that one set of experimental data can be re-examined with the same strain of cells, thereby establishing a base line which can be only roughly approximated in primary explant cultures. One objection raised to this method of tissue culture is that these cells maintained for long periods outside the body in a state of rapid proliferation become so altered that they are no longer satisfactory for studies in which it is desired to make some in vivo correlation. This thesis has some validation in that several such strains of cells have spontaneously undergone malignant changes, while others which were malignant have been observed to lose their ability to produce tumors.

The actual technique for planting replicate cultures is relatively simple and although requiring several items of special equipment, does not necessitate an excessive expense. The one prerequisite is that the cultures to be studied must be of the type which can be grown on glass or cellophane substrates. After the cells are scraped loose into the fluid medium, this suspension is passed through a double sieve which has two platinum irridium gauzes, of 80 and 150 meshes respectively. This breaks up, or removes, the cell clumps from the suspension making it more uniform in nature. The suspension is then placed in a special stirring burette, from which it is dispensed in equal volumes to the new culture flasks.

The quantitative determinations, likewise, can be done with a minimal amount of effort and outlay for equipment. Replicate cultures, of course, are a prerequisite for this procedure and the technique for obtaining them has just been discussed. Cultures are prepared for nuclei enumeration by the following procedure: the cells are scraped loose from the glass, citric acid solution is added and the flasks are returned to the incubator for two or more hours. The citric acid digests away the cytoplasm and loosens from the glass any cells missed at the time of scraping. This suspension of nuclei is centrifuged, part of the supernatant fluid removed, and additional citric acid solution containing 0.1 per cent crystal violet added. The stained nuclei are then suspended in a known volume of a methocellulose-citric acid solution in 10 ml. graduate cylinders. Aliquot portions are taken up in special pipettes, and after agitation the nuclei are counted in a hemocytometer. By making such counts at the time a series of cultures are planted and during the course of an experiment, it is possible to obtain a very accurate evaluation of the effect of some added substance or some condition on the experimental cultures in respect to counts made on appropriate controls.

The practical applications of these long-term glass substrate serial cultures and the methods of handling them are both many and obvious. A variety of viral agents have been successfully cultivated in one cell strain or another, in situations where the cell population was under control and where it was possible to repeat tests under exactly the same experimental conditions. A very uniform viral infection can be induced in the culture by adding the agent to the cell suspension while it is being mixed in the stirring burette prior to inoculation of the cells into the culture flasks. These cultures can also be used in screening or studying the mode of action of possible antiviral drugs or antibiotics. Many such agents reported in the literature as having some inhibitory effect on virus multiplication in tissue culture probably could be eliminated by re-examining them with quantitative studies of their effect on inhibition of cell growth. The difference between no inhibition of cell growth, and that amount which the eye can accurately detect by microscopic observation is considerable, and it is in this range that possible errors in interpretation of results, of tests for viral inhibitors, are made.

Earle and his associates are using these methods of tissue culture and are finding answers to age old disputes and are replacing some of the arbitrary measures generally employed with new established facts (8). Among these are the determinations supported by quantitative data of the best concentrations of the ingredients of culture media, the effect of inoculum size on the probability of successful subculture (9), and many other such factors which had previously been guessed at and still are by many. Outstanding among the contributions of these investigators has been the development, first, of a means of sterilizing embryo extract (10), second, of the preparation of a protein free ultrafiltrate of embryo extract (11), third, the determination of the chemical composition of the extract (12), and fourth, the suggestion that the role of embryo extract is that of a potentiator for the serum which is actually the main source of food in the culture medium (8). These studies were possible only because these workers had a quantitative control over their system for evaluating the effect of the various factors on cell proliferation.

Further uses for these methods can be found in the screening of many compounds for various purposes. The use for antiviral agents has already been mentioned. With cultures of both normal and malignant cells, substances can be evaluated quantitatively for any differential inhibitory effect they might have on tumor cells as opposed to normal ones. General cellular toxicity studies can also be made where it is desirable, for example, to compare two lots of a drug, or two competing products of the same pharmacological action.

The application of this type of tissue culture, or cell culture, as it should more appropriately be called, to practical problems in various research fields, control and testing functions in industry or elsewhere, can be steadily increased by the establishment of more and varied strains of cells and by more investigators taking up this approach to cell cultivation.

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Factors Affecting Growth of Mammalian Viruses in Vitro

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Multiplication of viruses, rickettsiae and some other micro-organisms is intimately associated with living tissues. This association presents certain difficulties in the determination of growth requirements of these agents. On the other hand, it is possible to investigate host-parasite relationships under extremely favorable conditions.

A number of viruses and rickettsiae have been propagated experimentally in laboratory animals, embryonated eggs and in excised tissues. The following discussion will be limited to a few factors which influence growth of these agents *in vitro*—i.e., in the test tube.

The methods suitable for the cultivation of viruses and rickettsiae are three: 1) The Carrel technique, using fragments of tissues embedded in a drop of clotted plasma. This procedure was introduced in 1927 (1). 2) In the following year, Maitland and Maitland (2) achieved the same result using tissue fragments bathed in Tyrode's solution containing a little normal serum. This is not a true tissue culture procedure since little or no proliferation of tissues occurs. 3) In 1939, Gey and Bang (3) and, in 1940, Enders and associates (4) introduced the roller tube method for cultivation of viruses. This procedure permits cultivation of an infectious agent without interruption for several weeks.

Time. The growth curve of a virus cultivated *in vitro* usually can be divided into lag, logarithmic, stationary and decline phases. The time of incubation after which the greatest concentration of virus is attained varies with the infectious agent. For example, the vaccinia virus, when cultivated in the presence of chick embryonic tissues at 33° C., reaches a maximal titer on the fifth day of incubation. The influenza virus grows more rapidly, reaching a maximal concentration within 72 hours. Rickettsiae grow slowly and titers are greatest after a week (5). In roller tube cultures, titers of viruses vary somewhat during the period of incubation (4).

Temperature. Temperature exerts a profound effect on the growth of viruses and rickettsiae. Herpes simplex, vaccinia and infectious myxomatosis viruses grow best at a temperature of about 35° C. (6). Vaccinia virus may survive incubation at 45° C. for four days but herpes and myxoma viruses fail to withstand a temperature of 40° C. (6). Low temperatures favor growth of rickettsiae; *R. prowazeki* develops best at 32° C. (7).

Oxygen tension. The usual tissue culture procedures provide a rather high oxygen tension and this apparently favors viral proliferation. The effect of oxygen tension can be demonstrated in cultures of vaccinia virus incubated with and without vaseline seals. At low oxygen tensions, growth of the virus occurs slowly and titers are low (8). It may be anticipated that viruses will be demonstrated which will grow best at a reduced oxygen tension. Maximal growth of rickettsia occurs in tissue cultures in which cellular metabolism is at a low level (9).

Nutritional requirements. Viruses and rickettsiae tend to exhibit a high degree of host and tissue specificity. Vaccinia virus, adapted to the rabbit, will grow as well in chick as in rabbit embryonic tissues but grows poorly or not at all in mouse or rat embryonic tissues. The virus can be adapted to the mouse and then will grow as well in mouse as in chick embryonic tissues. The failure of a strain of vaccinia virus, adapted to the rabbit, to multiply in mouse embryonic tissues may be due either to the presence of harmful substances in the mouse tissue or to the lack of essential metabolites. Viral development occurs uninhibited in a mixture of mouse and chick embryonic tissues.

Information concerning the dependence of viruses on specific metabolites can be obtained by use of metabolite antagonists. A substance structurally related to a metabolite may be utilized by enzyme systems of the host or parasite in place of the metabolite. If the analogue is unable to serve the same functions as the metabolite, it may block or inactivate the activity of enzyme systems necessary for proliferation of the parasite. If the inhibitory action of the substance is counteracted by the corresponding metabolite, the analogue is designated a metabolite antagonist and it is assumed that the metabolite is required for development of the parasite.

On the basis of data available, it would appear that the purine, adenine, is essential for growth of vaccinia (10) and Russian spring-summer viruses (11). Adenine, guanine and xanthine seem to be required for multiplication of the psittacosis virus (12). Folic acid is essential for the psittacosis and meningopneumonitis viruses (13, 14, 15). Phenylalanine is required for development of the vaccinia virus (16) and methionine for the influenza (17) and poliomyelitis (Lansing) viruses (18).

These data suggest certain possibilities concerning the investigation of growth requirements of viruses and rickettsiae. Although the information available is limited, methods for exploration of the field have been developed and rapid progress can be anticipated. By use of the roller tube technique, observations can be made over prolonged periods. It should be emphasized, however, that biological relationships which prevail *in vitro* may differ greatly from those which exist *in vivo*. Therefore, parallel investigations utilizing both experimental animals and excised tissues are desirable in order to gain an understanding of the basic mechanisms governing viral and rickettsial proliferation.

Summary. Examples of the effect of certain physical and nutritional factors on viral and rickettsial growth *in vitro* have been presented. Tissue culture procedures provide an important means for the determination of biological properties of viruses and rickettsiae. Relationships demonstrated *in vitro*, however, do not necessarily apply in the living subject.

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Counting Infectious Viral Particles in Tissue Culture

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Virologists look upon the research carried out with the bacteriophages of the T group (1) as establishing a pattern to be followed in the study of the kinetics of infection and genetics of other viruses. However, the lack of a precise method for the estimation of viral growth and the separation of the progeny of single organisms has been the most important stumbling block in the application of the results of bacteriophage research to animal viruses. Two attempts to develop such quantitative animal virus techniques will be described.

The first, a method developed by Dulbecco (2), is a faithful reproduction of the seeded agar plate used in the study of bacterial viruses. The virus must be highly destructive of host cells. The agent of Western equine encephalomyelitis was found to be the most suitable. The host cells are the chick embryo "fibroblasts," separated from other tissue elements by treatment with trypsin and repeated centrifugation. These cells, derived from all parts of decapitated 9-day-old chick embryos, do not form pure cultures, of course, but are uniformly susceptible to infection with many of the cyto-pathogenic viruses. Under appropriate conditions of cultivation, they will readily form a single sheet of cells covering the entire floor of a culture flask.

The Petri plates, inadequate for tissue culture work, are replaced by 80 mm. Carrel flasks. Single sheets of "fibroblasts" are formed therein after 48 hours' incubation of the cellular inoculum at 37° C. Uniform distribution and absorption of the virus to the cells is achieved by temporarily removing the nutrient fluids and covering the cells with a small volume (0.5 ml.) of viral inoculum. The virus is maintained in the immediate vicinity of the original site of cellular penetration by the inclusion of agar in the medium added after inoculation. After 3 days of additional incubation, clearings of lysed cells can readily be detected. They are analogous to the "plaques" produced by bacteriophages.

Several separate experiments indicate that the number of clearings is inversely proportional to the dilution of the virus. Therefore, it can be assumed that each clearing is produced by the progeny of a single virus particle. The results obtained by this method agree with those of routine chick embryo titration.

A second quantitative animal virus technique has been developed by Weiss and Huang (9). This method is quite different from Dulbecco's for it involves the microscopic counting of infected cells.

The virus chosen for study was the agent of feline pneumonitis, which is large enough to be detected in ordinary light microscopy and forms characteristic inclusion bodies (7). Unlike the virus of Western equine encephalomyelitis, however, it has a high degree of cellular specificity and will grow well, outside its normal host, only in the entodermal cells of the yolk sac.

The characteristics of the cells of the yolk sac cultured *in vitro* have been studied extensively by Grodzinski (3) and Thomas (6). Their observations greatly facilitated the search for the area of the chick embryo which forms the largest colonies of entodermal cells *in vitro*. This area was finally located in a narrow band of the avascular membrane, just peripheral to the sinus terminalis of the 4-day-old embryo. Cleanly cut and properly embedded explants from this area, 2 mm. in diameter, give rise, in 4 days, to single layers of cells covering an area of approximately 1 cm^2. The cells of these colonies are typically large and vacuolated, containing white and yellow yolk, and, as far as it can be judged morphologically, are all of the same type. A mixture of one part chicken serum and three parts Hanks' balanced salt solution (4) is an adequate nutrient. The cultures thus prepared are ready for inoculation. The viral suspension is added and the cultures shaken for 4 hours.

A feline pneumonitis virus particle which successfully invades a cell develops in it for approximately 48 hours before lysing it and infecting other cells. The infected cells are readily recognized by ordinary microscopy. The viral inclusions resemble those described in the intact chick embryo (7, 8) and are readily distinguished from other viruses of the same group, such as the agent of murine pneumonitis virus. Cultures fixed and stained approximately 30 hours after inoculation, before any of the cells have lysed, reveal well-developed inclusion bodies which can be counted and serve as a gauge of the original inoculum.

Unlike the agent of Western equine encephalomyelitis, feline pneumonitis is not very virulent. Moulder and Gogolak (5) estimated that approximately 100 particles are necessary to initiate infection in the chick embryo. In tissue culture many factors affect the efficiency of infection. For example, the infected cell counts vary significantly in different embryos as well as in different areas of the same embryo. The composition and volume of the nutrient medium and the handling of the culture after inoculation also influences the results. Shaking the cultures gently for 4 hours increases the infected cell count. Most of the factors affecting the infected cell counts are probably still unknown, and are possibly responsible for the fairly large deviation from the mean still encountered in this procedure.

In spite of the above mentioned difficulties, the infected cell count method of estimation of the size of a viral inoculum, under the best conditions, is as sensitive as the routine chick embryo titration and considerably more accurate. Counts carried out in quadruplicate are usually able to reveal 3-fold and often 2-fold differences. It is also apparent that the counts are inversely proportional to the dilution of the virus and, therefore, indicate that a single successful particle is sufficient to start infection of a cell.

The details of the two methods described above are not comparable. Fibroblast cultures are obviously as unsatisfactory for feline pneumonitis virus as entodermal cell cultures for Western equine encephalomyelitis. Each method is adapted to a particular type of virus: the first for highly virulent organisms and the second for those which form inclusions. They greatly simplify the study of the relationship of these viruses to their host cells and offer the possibility of extending to animal viruses research previously confined to bacteriophages.

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BOTANY

Chairman: H. R. YOUSE, DePauw University

DANIEL DEN UYL, Purdue University, was elected chairman for 1953.

ABSTRACTS

The effect of starvation upon the ability of corn root tips to respire sugars. RAYMOND E. GIRTON, Purdue University.—One centimeter corn root tips were starved at warm room temperatures for overnight periods or longer. The ability of these root tips to respire various sugars was then tested by means of the Warburg manometer technique. Marked increases in the oxygen uptake by the starved roots as the result of sugar feeding was noted in contrast to the results obtained with non-starved roots. A comparison of the ability of these roots to utilize several different sugars was included in this study.

Plant communities on organic terrain in the northern Mackenzie Basin, Canada. ALTON A. LINDSEY, Purdue University.—The principal community types on organic terrain visited in Mackenzie District between 60° 50′ N. Lat. and 69° 20′ N. Lat., excepting mesic forest sites, are described. Five distinct moist tundra communities on sand, determined by exposure and drainage conditions, form an intimate mosaic. In the transition spruce forest farther southeast, a very large type of raised-center polygon has the center dominated by a flat stand of Cladonia and Cetraria, dotted with hummocks of Sphagnum and low ericaceous shrubs. An inland saline meadow exemplifies a habitat unique in this region. Bogs with true floating mats are rarely found, consequently Sphagnum is far less important in low wet sites than Camptothecium, Aulacomnium, and Dicranum. Where frequent stream flooding brings in silt, and on pond borders, reedmarsh communities are very prevalent. Their dense emergent growth, dominated by *Carex aquatilis*, *C. rostrata*, or *Equisetum limosum*, initiates peat accumulation. Communities upon deeper organic deposits include (1) tussock sedge—low willow, (2) ground birch "muskeg," (3) tall clumped willows, and (4) closed stands of tall willow and paper birch. These are not all related successionally. The black spruce—tamarack community is the edaphic climax in mature bogs in both the northern transition forest of the Precambrian Shield, and the Mackenzie Lowlands region. It has a shrub stratum of low, mostly ericaceous chamaephytes, and a ground cover of non-Sphagnum mosses and *Equisetum scirpoides*.

The phytoplankton of Lake Wawasee, Kosciusko County, Indiana. WILLIAM A. DAILY, Butler University, and EVERETT E. MINER, Syracuse, Indiana.—This study is based upon 41 plankton net collections made during 1950 and 1951. During 1951 samples were collected approximately weekly from April 28 to October 30. Twenty-nine genera and forty species representing six classes of the algae are recorded. (To be published in the Butler University Bot. Stud. XI.)

Hardwood tree planting on coal mine spoil banks. DANIEL DEN UYL, Purdue University.—The first organized forest tree planting on strip mine spoil banks in Indiana was begun in 1928. Although some results have been secured from these early attempts to reforest spoil banks, the great change in machinery used in mining operations has resulted in new land use problems for which no immediate solutions were available. Forest tree planting has expanded during the past fifteen (15) years and at present the member companies of the Indiana Coal Producers Association are planting about one and one-half million trees a year. Since the passage of strip mine legislation in 1941 and 1951 which requires the revegetation of spoil banks considerable attention has been given to revegetation problems. Consequently in co-operation with the Indiana Coal Producers Association investigations were started in 1949 to determine which species of hardwood trees are best suited for planting of the spoil banks of Indiana. Ten species of hardwoods have been tested on sixteen experimental plots throughout the strip mine area in Indiana.

Based on their survival records and early initial growth black locust, *Robinia Pseudo-Acacia* (L.), green ash, *Fraxinus penn. var. lanceolata* (Borkh.), cottonwood, *Populus deltoides* (Michx.), silver maple, *Acer saccharinum* (L.), sycamore, *Platanus occidentalis* (L.) and sweet gum, *Liquidamber styraciflua* (L.) are the species which up to the present time show the most promise of growing on spoil banks. Species which are apparently not suited for the spoil banks are ailanthus, *Ailanthus altissima* (Mill), red maple, *Acer rubrum* (L.), tulip poplar, *Liriodendron tulipifera* (L.), and black walnut, *Juglans nigra* (L.).

A comparative study of two established ponds. ATWELL M. WALLACE and JOHN R. THOMPSON, Ohio University.—The recent interest in farm ponds and the small number of studies on ponds, especially those which have been established for a number of years, prompted the following study. The two ponds considered are on the Athens State Hospital grounds and were constructed approximately 75 years ago. They have not been drained or disturbed for at least 15 years prior to this investigation.

Though connected near the water source by a small channel, it has been observed that the amount of algae and the species present varied greatly on the same dates. An attempt was made to discover what factor or factors might be causing this difference.

From the time the ice began to melt in February, 1950, until the first of May, 1950, records were made at the surface and 0.5 m beneath the surface of the temperature, light intensity, dissolved oxygen, free carbon dioxide, and pH. These readings were obtained each four days and the data utilized in interpretation of the total algae estimates and relative abundance of species as determined by population counts.

Both ponds are on the north base of a hill. Light measurements showed one pond to be significantly shaded by the steep hillside. The shaded pond averaged 2.3° C. cooler than the relatively unshaded pond. The dissolved oxygen remained near saturation in both ponds during the period of study. The free carbon dioxide content remained consistently higher in the shaded pond. The pH ranged from 7.1 to 8.1 in the shaded pond and 7.6 and 8.5 in the open pond. Throughout the study the open pond contained approximately twice the quantity of filamentous algae as the shaded pond and was approaching a solid mat at the close of the period.

The only significant factor in the algal populations of these two ponds appears to be the difference in light intensity which is reflected in the higher temperature of the open pond, the increased algal population of it, and relative proportions of the different species present on particular dates. The higher rate of photosynthesis in the open pond probably accounts for the decrease in free carbon dioxide and consequent increase in pH.

Secondary succession in seven stands of red maple-sweet gum forests in Ripley County, Indiana. J. E. POTZGER and A. N. LIMING.—The quadrat study shows that the number of important dominants is large, and all show a high degree of fidelity in the seven stands, indicating great uniformity in this type forest. In terms of abundance of stems one inch or above in diameter they rank: red maple—sweet gum—American elm—shagbark hickory—pin oak—American ash—beech. Compared with the dominants in a mature stand (Klein woods, Jennings County) the Ripley County stands are essentially of the same structure. While sweet gum and red maple are the most aggressive early invaders, the developing forests show no typical succession, which is so common in the climax forest of Indiana. It seems, however, that beech, tulip poplar, and white oak are not so abundant in early succession as in the mature forest.

The morphological effects of petroleum naphtha on pine seedlings. J. DONALD LACROIX, Purdue University.—This investigation was undertaken to determine if there are correlations between stages or conditions of growth which make the seedlings more or less susceptible to the herbicide. Seedlings of slash pine *(Pinus caribaea)*, white *(P. strobus)*, red *(P. resinosa)*, and scotch *(P. sylvestris)* were grown in the greenhouse during the winter and summer and were subjected to either pre-emergent or post-emergent treatments of approximately 200 gallons per acre at the following stages: (1) The soil sprayed and the seed planted; (2) the seed planted and the soil sprayed; (3) the seed planted and the soil sprayed after thirteen days; (4) seedlings two months old; (5) seedlings approximately seven months old; (6) one-year-old seedlings. The use of Standard Weed Killer at about 70 gallons per acre reduces the weeding problem and will cause little damage if applied while the seed coats are still on the cotyledons, or is applied after the trees have reached one year of age but at greater amounts, damage will result to the seedlings in both pre-emergent and post-emergent treatments. Pre-emergent sprays rather noticeably reduce the percentage of germination of all species and slash pine with seed coats is intolerant. Applications on five to nine-month-old slash pine result in needle burning and severe damage to the leaves, growing-point and cotyledons. One-year-old white pines appear to be highly susceptible.

Some aspects of plant succession on abandoned farm lands of southeastern Indiana. PAUL WESTMEYER, North Vernon, Indiana.—Thirty-six abandoned fields in southeastern Indiana were sampled by quadrats to determine present dominants. The fields were chosen so that all were of white clay soil and were flat and poorly drained.

Putting the results together in order of the ages of the fields since abandonment shows the following apparent succession. First year—*Ambrosia artemisiifolia*, second year—*Setaria glauca* with *Bidens frondosa*, *Cyperus*, and *Erigeron annuus* present under certain conditions, third year—*Dactyloctenium aegyptium* with *Acer rubrum* beginning to develop and also with *Rubus villosus* and *Xanthium spinosum* occasionally present in sizable amounts, fourth year—*Aster multiflorus* with *Fraxinus americana* beginning to develop, fifth year—*Solidago* with *Ulmus americana* beginning to develop and usually with some *Aster* still present, sixth year—*Acer rubrum* is dominant, eighth to twenty-sixth years—*Liquidambar styraciflua* and occasionally *Acer rubrum* in large numbers, thirty-fourth year—*Liquidambar*, *Quercus*, and *Carya ovata*, and fortieth year—mixed mesophytic forest.

Factors relating to the development and germination of certain fungus sclerotia. C. L. PORTER and JACK G. THOMAS, Purdue University.—The importance of sclerotia in the life history of fungus pathogenes has been discussed by many workers, but little attempt has been made by Mycologists to determine the details of their formation, the circumstances under which they may be formed, or the environmental conditions favorable to their germination and further development. Since it is assumed that many soil borne pathogenes over-winter in the sclerotial stage it is of the greatest practical importance to know whether their formation might be delayed or prevented by appropriate cultural practices.

This investigation is an attempt to answer some of the questions concerning the circumstances attending sclerotial formation and germination.

New plant distribution records and collecting places of Parke and Fountain Counties, Indiana. FRANKLIN B. BUSER, University of Illinois.—The number of vascular plant species recorded for Parke County is 592 and for Fountain County 529, as listed by Deam in his Flora of Indiana and by subsequent issues of the Indiana Plant Distribution Records. Extensive collections, undertaken during the spring and summer of 1952, add considerably to these figures. For Parke County, 54 new county records are proposed and 146 for Fountain County. This brings the present totals for the two counties to 646 and 675 respectively. A specimen of each record has been deposited at Butler University. Such collecting places as the Silverwood "Swale," Covington Swamp and the Switzer Place in Fountain County, and the Cashet Swamp and the Howard-West Union Road in Parke County are considered worthy of additional floristic attention.

A role for acetic acid in tomato fruit-set. A. C. LEOPOLD, FRANCES S. GUERNSEY, and RUBLE LANGSTON, Purdue University.—Studies of tomato fruit-set have been carried out using flowers of a self-sterile strain of John Baer tomatoes, excised and cultured on agar media. It has been found that acetic acid alone in the medium has little or no promotive effect on fruit-set. However, the addition of 10 ppm pantothenic acid results in a large response to acetic acid (55-58%). This response is specific for acetic acid among the 8 acids tried, and is prevented by 10^{-4} M fluoroacetate. A liver concentrate rich in coenzyme A produces the same effect as pantothenic acid, and the simultaneous addition of the 4 known constituents of coenzyme A produces a larger response (73% set) than pantothenic acid alone. These observations plus a low assayable pantothenic acid content in tomato ovaries suggest that the entry of acetic acid into the tricarboxylic acid cycle can promote fruit-set, but such entry is normally limited due to limiting quantities of coenzyme A present.

The effect of nitrogen upon fruit abnormalities in the tomato. FRANCES SCOTT GUERNSEY and A. C. LEOPOLD, Purdue University.—Experiments were conducted varying the nitrogen level and the setting procedure in Michigan State Forcing tomatoes. The following effects on tomato fruit development under spring greenhouse conditions were found:

(1) The incidence and severity of puffiness was proportional to the nitrogen supply.

(2) PCA (parachlorophenoxyacetic acid) as a fruit-setting agent did not increase puffiness when sprayed on the front of the flower, except at excessive nitrogen levels.

(3) PCA sprayed on the back of the flower increased puffiness at every nitrogen level.

(4) Blossom-end rot, green locules, and white placentas were all most common at high nitrogen levels.

(5) Green locules and white placentas were almost entirely restricted to growth-regulator-set fruits. Blossom-end rot, however, was found with equal frequency regardless of the setting procedure followed.

A study of natural species—hybrids in the genus *Tragopogon*. DALE M. SMITH and A. T. GUARD, Purdue University.—Several locations were found in Tippecanoe County, Indiana, where the species *Tragopogon porrifolius* L., *T. pratensis* L., and *T. dubius* Scop. were found growing together. In each of these locations plants which were obviously hybrids between two of the species were found. The F_1 hybrid plants were almost completely sterile and there was little evidence of either back-crossed or F_2 plants.

Aneuploidy in Claytonia virginica. NORMAN V. ROTHWELL, Indiana University.—In the taxon, *Claytonia virginica*, the existence of at least nine different chromosome numbers has been established. The haploid numbers found so far form an aneuploid series as follows: $n = 8, 9, 11, 12, 14, 15, 16, 18$, and 24. It has not as yet been found possible to determine the chromosome number of any single plant by morphological examination.

Cytological examination suggests that the haploid number of eight is the basic one for the taxon and that the other numbers have arisen from it. That some of the extra chromosomes are homologous to those in the basic set of eight is indicated by the multivalent configurations which have been found in the $n = 9, 11, 12, 15, 16$ and 18 material. The $n = 16$, 18, and 24 plants are believed to be autopolyploids of $n = 8, 9$, and 12.

Non-disjunction has been found in some n = 8 plants. Other n = 8 plants have been found in which one-to-four univalents lag at first anaphase. These laggers divide at first anaphase and give rise to some cells having more than eight chromosomes. In such a way n = 9, 11, and 12 could arise from a basic set of eight.

The n = 14 and 15 plants are believed to have arisen from n = 16 and possibly also from n = 18 as a result of chromosome loss through non-disjunction.

A study of the relationship of pre-illumination, morphology and response in the slit pea test. JOSEPH M. RIEDHART and CARL A. LEOPOLD, Purdue University.—An investigation was made of the relationship of morphology, pre-illumination, and response in the slit pea test. Plants were grown in total darkness, others exposed to 1, 4, and 7 hours of red light per day from the time of planting to the time of harvesting. Macroscopic and microscopic observation were made. It was found that duration of pre-illumination affected plant height, color, leaf size, and sturdiness. And it was also found that duration of pre-illumination, while affecting cell length, did not affect initial negative curvature but will affect positive curvature. It appears that two factors are involved in this response-differential growth and differentiation. It was also found that the orientation of the vascular bundles will influence the degrees of curvature and the plane of curvature.

Preliminary report on the investigation of bud-break in woody plants of Porter County, Indiana. ROBERT J. KUSTER, Valparaiso University.—During the winter of 1951-52 an investigation was made concerning the time of bud-break on a number of woody plants found on the campus of Valparaiso University.

Twenty-three species were selected, healthy appearing twigs were gathered, brought into the laboratory and placed in test tubes containing tap water. Collections were made monthly from November through April, twig ends were re-cut and test tubes washed out every second week. Water was added as needed and records of observations were kept.

Many of the twigs died without outward evidence of response, some whose buds began to swell did not succeed in opening them. Of the 23 species examined, 8 gave very little or no response, 5 opened flower buds, 8 opened leaf buds and 2 showed both types.

Sugar maple, basswood, 2 species of pine, 2 of spruce, and 2 of buckeye responded very poorly. Ginkgo, silver and red maple, white ash, lilac, forsythia and privet responded consistently. With the latter group a decreasing lapse of time was noted month by month from the time of collection until bud-break. The actual elapsed time varied with the species and there seemed to be no correlation within a genus, some species being consistently later in this respect than others.

Ask the biologist. RICHARD R. ARMACOST, Purdue University.—To coordinate services to the schools, there has been established at Purdue a dual professor system whereby certain professors are members of both the School of Science and the Division of Education. These representatives of the University cooperatively and directly work with the high schools of Indiana, providing various types of services and aids to high school science teachers and their students. A weekly, taped radio program "Ask the Biologist," is one of these services.

The Purdue University Department of Biological Sciences sponsors "Ask the Biologist" as a means of bringing, via radio or tape recordings, many members of its staff to the high schools of Indiana. This series consists mainly of question-answer broadcasts and interviews centered around biology topics of interest to high school students and their teachers. No speeches are given, and a valiant effort is made to present material in such a way that it is understandable, educational, and enjoyable.

The Purdue University Department of Biological Science feels that "Ask the Biologist" can be a means of contributing many fine ideas, and for that matter inspiration, to biology students and teachers of the Indiana high schools.

What is happening to the Indian varieties of corn? PAUL WEATHERWAX, Indiana University.—Information accumulated through many years of observation on agriculture in our Southwest indicates that community taboos against alien plants are breaking down, and this is having a profound effect on the primitive varieties of corn. One manifestation of this is the production of monstrous forms. From this can be drawn some conclusions as to the origin of midwest varieties.

Peculiarities in the embryology of *Tripsacum dactyloides*. LOIS FARQUHARSON, Indiana University.—The genus *Tripsacum* has long been of interest because of its close relationship with corn and the role which it may have played in the origin of the cultivated plant. Both diploid and tetraploid strains of *T. dactyloides* exist in the U. S., the latter type being found in southern Indiana. The embryology of the diploid plants is similar to that of corn. In the polyploid, however, twin embryos are frequent and triple embryos occur occasionally. These are usually located in one embryo sac although two embryo sacs have been observed in a few ovules. Apomixis undoubtedly occurs and embryos of over 100 cells are found although no endosperm is formed. Chromosome counts of twin plants are in progress.

Preliminary investigations in the cyto-genetics of some *Asters* in northern Indiana. ALBERT L. DELISLE, Notre Dame.—Investigations to determine the chromosome numbers of several species of wild Asters growing in northern Indiana were made. Applications of colchicine with a view to induce ploidy in these Asters were successful, so far, in only one species, *Aster novae-angliae* L.

As a result of reciprocal hybridization studies in *Aster novae-angliae* L., and *A. ericoides L.*, it was noted that the maternal parent had a marked effect on the size of the resulting hybrid embryo. This effect of maternal inheritance on the size of the resulting hybrid embryo will be further investigated.

Hydrogen ion concentration in relation to absorption of water by *Poa pratensis L.* GORDON K. RASMUSSEN, Purdue University.—In this preliminary study five two-gram lots of seed were each soaked in unbuffered solutions, pH 3, 4, 5, 6, 7, 8, and buffered solutions of pH 4.8, 5.4, 6.0, 6.6, 7.2, and 7.8 for various periods. The greatest increases in weight occurred during the first twelve hours. The very greatest increase in weight occurred in the lot of seeds soaked in the unbuffered pH7 solution and amounted to 51.5 per cent. Of the seeds soaked in buffered solutions, those soaked in pH6.0 and pH7 solutions for twelve hours increased 49 per cent in weight. After the initial twelve hours there was a leveling off in the amount of water absorbed.

The change in pH of the unbuffered solutions was measured after each period of soaking. Each unbuffered solution changed to a pH 5.8-6.1 within 72 hours.

The same tests were run on merion bluegrass, a variety of *Poa pratensis*. Merion bluegrass absorbed more water (52-70%) in each period of time than did Kentucky bluegrass. The pH of the unbuffered solutions changed to 5.7-6.5 within the 72-hour period.

The use of the Verduin method for measuring the photosynthesis and respiration of aquatic plants. DON E. SEAMAN, Purdue University.—The rates of photosynthesis and respiration of aquatic plants are measured under near-natural conditions by a method involving the determination of Co_2 exchange through the use of pH and total alkalinity measurements. Results are expressed as micromoles of CO_2 either absorbed or evolved depending on the process being studied. The method is useful as a tool for research in aquatic plant physiology as well as in ecological studies. The results of some studies on phosphate fertilization and on depth of immersion are discussed to illustrate the use of the method in different types of studies and with various kinds of plant material.

The phylogenetic value of pollen morphology as illustrated by the Magnoliaceae. JAMES E. CANRIGHT, Indiana University.—During the course of a comparative morphological survey of the Magnoliaceae *(sensu strictô)*, pollen of 50 species was investigated. In all cases, the pollen grains were found to be more or less ellipsoidal and monocolpate, i.e., with a single longitudinal germinal furrow. The sculpturing of the exine is minute to non-existant in most cases, therefore positive identification of species and even genera in this family from pollen samples is usually unreliable. The verrucosely-sculptured exine of pollen grains of *Liriodendron*, incidentally one of the most specialized genera in this family, provides the only significant exception to this rule. Although size measurements of pollen revealed that this family contains both among the largest and the smallest grains recorded for the angiosperms, attempted correlation of pollen size with degrees of polyploidy gave inconclusive results. In the few specimens where coherent tetrads were seen, it was discovered that not only were the tetrads of the comparatively uncommon tetragonal type, but also that the germinal furrow is distal in position. This discovery lends further support to the pollen phylogeny postulated by Wodehouse. It is significant that pollen grains of the medullosan seed ferns, Cordaitales, Bennettitales, Cycadales, and Ginkgoales are all of the monocolpate type. Among dicotyledons, only certain families in the ranalean complex (which includes the Magnoliaceae) are characterized by the retention of this ancestral type of pollen; all other dicots possess the more specialized tricolpate or derived types of pollen.

Work at the Mont Tremblant Biological Station, Quebec. J. E. POTZGER and ROBERT LIPSCOMB, Butler University, Indianapolis.—In March, 1952, Professor Albert Courtemanche, Director of the Biological Station, requested the senior author to spend all or part of last summer as guest member of the Station's science team, to make pollen analyses of bogs in the Laurentian Shield, where the Station is located on Lake Monroe. The Biological Station is only three years in operation but it radiates the stimulating enthusiasm of youth. It is very obvious to a visitor that the scientists and government officials of Quebec are intensely interested in the scientific facts underlying the wealth of Canada's biological inheritances. Their enthusiasm is, indeed, very stimulating. The work is being pushed by such leaders as Dr. Gustave Prevost, Director Quebec Biological Bureau, and Albert Courtemanche, Director of the Biological Station. The station sponsors some phases of applied science but especially the pure sciences, such as pollen analyses, regional study of dragonflies, desmids, and others. Use of plane to locate suitable bogs and the Bendix Depth Finder employed to determine contour as well as depths of lake basins were ultra-modern aids to a pollen analyst. The junior author aided in the field and laboratory work and served as chief photographer on the trips. The history of Quebec forests is very complex, and it seems to reflect the influence of the post-glacial history of the St. Lawrence valley.

Opportunities in the Indiana flora. CHARLES B. HEISER, JR., Indiana University.—Through the efforts of Charles C. Deam and other botanists in the state, Indiana has a flora that is exceedingly well known. As a result of this work the Indiana flora offers excellent opportunities for the study of taxonomic problems connected with variation and hybridization. These problems can be approached through the detailed analysis of natural populations by means of mass collections, through studies of chromosome number, and whenever possible through actual cultivation of plants and hybridization studies. Such approaches have already proved rewarding as shown by Charlotte Avers' study of *Aster*, Norman Rothwell's study of *Claytonia virginica*, and Robert Long's and Dale Smith's investigation of the perennial *Helianthi* of Indiana. In connection with the cytological studies it might prove feasible to develop an atlas of the chromosome numbers of Indiana plants.

Variation in Heliopsis. T. RICHARD FISHER, Indiana University.—There has been considerable confusion in regard to the taxonomic status of *Heliopsis helianthoides* (L.) Sweet and *H. scabra* Dunal. The former taxon in its purest form centers around Virginia, West Virginia, and Pennsylvania, whereas the latter centers in the area of North and South Dakota, Nebraska, and Minnesota. Seven characters have been chosen for study and they reveal a gradual intergradation from one geographic range to the other. The range of intermediate forms seems to extend over an area of several hundreds of miles. The artificial hybrid between the two taxons has been produced and is fully fertile. In view of these facts it seems best to regard these two taxons as subspecies as has been done by Fernald in his treatment for Gray's Manual (1950).

The cultivated *Gaillardia*. WARREN P. STOUTAMIRE, Indiana University.—*Gaillardia pulchella,* an annual native of Texas, Louisiana, and states to the west, and *G. aristata,* a native perennial of the northwest section of the United States, have been grown in European gardens since the early nineteenth century. About 1856, a hybrid arose spontaneously in a French garden which was probably a tetraploid *(G. grandiflora).* At least six named varieties of *G. pulchella* and 15 of *G. grandiflora* are carried at present by nurseries here and in Europe. Experience in Bloomington shows that the tetraploid varieties are very variable and many named forms are not distinct.

The diploid forms of *G. pulchella* have escaped from cultivation into sandy areas along the Atlantic Coast from Virginia to Florida. Tetraploid *G. grandiflora* has also been found growing wild twice along railroad tracks in Indiana. Both species may persist as ruderal weeds.

Gaillardia pulchella has been treated with colchicine to produce autotetraploids and this species has also been crossed with *G. grandiflora* to produce triploids. Experiments are under way in an attempt to recreate *G. grandiflora* through crossing of *G. pulchella* and *G. aristata.*

The Characeae of Indiana. FAY KENOYER DAILY, Butler University.—About 500 specimens of the Characeae collected from 56 counties in Indiana were studied. Previously reported specimens extant as well as many other collections were obtained and found to represent 19 species. A distributional study, key descriptions, illustrations, and citation of specimens have been prepared. (To be published in the Butler University Botanical Studies, 1953.)

Indiana Plant Distribution Records, XIII. 1952.

Genera are listed in the order used in Deam: Flora of Indiana, and species are given alphabetically within the genera. Symbols following the county in which specimens were collected indicate the herbaria in which confirming specimens have been deposited. Entities listed for the first time for the state are given in bold face followed by literature reference and name of collector. Nomenclature is in accord with that used in Gray's Manual of Botany, 8 ed., 1950.

Specimens deposited in the various herbaria have been collected by the following collectors: Butler University (B): Frank Buser, Delzie Demaree, Charles M. Ek, C. C. Deam, R. C. Friesner, Fr. P. E. Hebert, J. Johanna Jones, Jack McCormick, and F. A. Swink. Deam Herbarium (D): C. C. Deam, Ray C. Friesner. Chicago National History Museum (F): J. A. Steyermark and F. A. Swink. University of Illinois (I). E. J. Hill and G. N. Jones. Indiana University (IU): J. S. Brooks, Virginia Elm, Charles B. Heiser, Jr., R. C. Jackson, S. Matsunami, Lois Nicholson, Roy O'Neal, W. R. Quinn, J. L. Ricketts, J. H. Rothrock, Clarence Sebree, and Dale Smith.

The Committee maintains a card file showing published distribution of each entity within the state. Botanical workers needing such information may obtain distribution maps of any entity recorded in the Flora, or subsequently added in these reports, or may secure reprints of these reports, by requesting same from the secretary of this committee.

Taxonomic Entities

Botrychium dissectum f. *obliquum*, Hancock (B), Miami (B). *Osmunda claytoniana*, Fountain (B). *Dryopteris thelypteris* v. *pubescens*, Fountain (B). *Camptosorus rhizophyllus*, Jackson (B). X *Asplenosorus ebenoides*, Jackson (IU). *Tsuga canadensis*, Fountain (B). *Juniperus virginiana v. crebra*, Decatur (B).

Typha latifolia, Cass (B), Fountain (B). *Sparganium eurycarpum*, Fountain (B), Monroe (IU). *Alisma subcordatum*, Fountain (B). *Arundinaria gigantea*, Jackson (B). *Bromus inermis*, Boone (B). *Vulpia octoflora* v. *tenella*, Fountain (B). *Poa annua*, Fountain (B). *Eragrostis hypnoides*, Parke (B). *Uniola latifolia*, Fountain (B). **Agropyron repens f. aristatum** (Schum.) Holmb. Gray Man. 8 ed. p. 136. Hitchcock 2 ed. p. 232. Lake (B, F). Collected by F. A. Swink. *Hystrix patula* v. *bigeloviana*, Fountain (B). *Lolium perenne*, Lake (B, F). *Calamagrostis canadensis*, Fountain (B). *Muhlenbergia racemosa*, Cass (B). *Leersia lenticularis*, Fountain (B). *L. oryzoides*, Fountain (B). *Paspalum circulare*, Fountain (B). *Panicum boscii*, Fountain (B). *P. dichotomiflorum*, Fountain (B). *P. dichotomum*, Parke (B). *P. philadelphicum*, Fountain (B). *Echinochloa crusgalli*, Fountain (B). *Setaria faberi*, Fountain (B), Parke (B). *S. lutescens*, Fountain (B). *Cenchrus longispinus*, Fountain (B). *Andropogon elliottii*, Jackson (B). *A. scoparius*, Decatur (B). *A. virginicus*, LaPorte (B, F).

Cyperus filiculmis v. *macilentus*, Parke (B). *C. rivularis*, Fountain (B), Parke (B). *C. strigosus*, Fountain (B). *Scirpus atrovirens*, Fountain (B). *S. cyperinus*, Fountain (B). *S. lineatus*, Parke (B). *Eleocharis compressa*, Porter (B, F). **E. engelmanni f. detonsa** (Gray) Svenson. Gray Man. 8 ed. p. 254. Porter (B). Collected by F. A. Swink. **Carex acutiformis**, Ehrh. Amer. Midland Nat. 48:36. 1952. Gray Man. 8 ed. p. 372. St. Joseph (B, D, ND). Collected by Fr. P. E. Hebert. *C. albursina*, Porter (F). *C. aurea*, Porter (B). *C. bromoides*, Parke (B). *C. careyana*, Fountain (B). *C. comosa*, Parke (B). *C. granularis*, Fountain (B). *C. grayii*, Dubois (IU). *C. hirsutella*, Fountain (B), *C. hystricina*, Parke (B), Porter (B). *C. intumescens*, Lagrange (IU). *C. lupulina*, Fountain (B), Parke (B). *C. muskingumensis*, Fountain (B). *C. pedunculata*, Parke (I). See Flora, p. 274. G. N. Jones No. 11021. *C. platyphylla*, Fountain (B). *C. rostrata* v. *utriculata*, Parke (B). *C. scabrata*, Schwein. Gray Man. 8 ed. p. 348. St. Joseph (B, D, ND). Collected by Fr. P. E. Hebert. *C. squarrosa*, Fountain (B). *C. swanii*, Fountain (B), Marion (B), Parke (B).

Symplocarpus foetidus, Fountain (B). *Peltandra virginica*, Fountain (B). *Arisaema atrorubens* f. *viride*, Fountain (B), Montgomery (B), Shelby (B). *A. a.* f. *zebrina*, Fountain (B), Montgomery (B), Shelby (B). *Eriocaulon septangulare*, White (IU). *Heteranthera dubia*, Morgan (IU), *Juncus brachycephalus*, Fountain (B). *J. scirpoides*, LaPorte (B, F). *J. torreyi*, Fountain (B). *Hemerocallis flava*, Lake (F). *H. fulva*, Fountain (B). *Allium tricoccum*, Fountain (B), Hancock (B), Parke (B). *Lilium michiganense*, Fountain (B), Randolph (B). *L. superbum*, Crawford (B), Monroe (IU). *Erythronium albidum*, Parke (B). *E. americanum*, Fountain (B), Jackson (IU). *Ornithogalum umbellatum*, Fountain (B). *Polygonatum canaliculatum*, Cass (B). *Medeola virginiana*, Fountain (B). *Trillium flexipes*, Parke (B). *T. f.* f. *walpolei*, Jackson (IU). *T. sessile*, Jackson (IU).

Dioscorea quaternata, Jackson (IU). *D. villosa*, Hancock (B), Parke (B). *Iris virginica* v. *shrevei*, Hancock (B), Parke (B). *Sisyrinchium augustifolium*, Fountain (B). *Cypripedium calceolus* v. *parviflorum*, Kosciusko (B). *C. reginae*, Wabash (B). *Orchis spectabilis*, Fountain (B), Jackson (IU), Porter (F). *Habenaria flava*, Fountain (B), Parke (B). *Isotria verticillata*, Jackson (IU). *Calopogon pulchellus*, Cass (B), Randolph (B). *Liparis lilifolia*, Parke (B).

Saururus cernuus, Fountain (B). **Populus X jackii**, Sarg. Gray Man. 8 ed. p. 523. Lake (B, F), Porter (B, F). Collected by F. A. Swink. *Populus tremuloides*, Decatur (B). *Carya cordiformis*, Jackson (B). *C. ovalis*, Cass (B), Crawford (B), Decatur (B), Fulton (B), Miami (B). *C. ovata*, Decatur (B), Henry (B), Jackson (B). *C. tomentosa*, Miami (B). *Ostrya virginiana*, Jackson (B). *Fagus grandifolia*, Lake (I). *F. g.* v. *caroliniensis* f. *mollis*, Hancock (B).

Quercus bicolor, Fulton (B). *Q. coccinea*, Bartholomew (B, D), Jackson (B, D), Miami (B), Monroe (B, D), Starke (B). *Q. c.* v. *tuberculata*, Cass (B, D), Crawford (B, D), Harrison (B, D), LaPorte (D), Pulaski (B). *Q. ellipsoidalis*, Cass (B), Jasper (B), LaPorte (B), Miami (B), Newton (D), Noble (D), Porter (B), Pulaski (D, B), Starke (B), Steuben (D). *Q. e.* f. *depressa*, Cass (B), Fulton (B), Jasper (B), Lagrange (D), Lake (B), LaPorte (B), Marshall (D), Porter (B), Pulaski (B, D), Starke (B, D), White (B, D). *Q. falcata* f. *triloba*, Crawford (B, D). *Q. imbricaria*, Pulaski (B). *Q.* X *leana*, LaPorte (B, D), Sullivan (B, D). *Q. macrocarpa*, White (B). *Q.* X *paleolithicola*, Jasper (B). *Q. palustris*, Carroll (IU), Cass (B), Decatur (B), Fulton (B), Lagrange (IU), Miami (B). *Q. rubra*, Jackson (B, D), Lake (B). *Q. shumardii* v. *schneckii*, Lawrence (B, D). *Q. velutina*, White (B).

Ulmus rubra, Jackson (B). *Celtis occidentalis* v. *canina*, Parke (B). *Humulus lupulus* (B), Posey (IU). *Laportea canadensis*, Fountain (B). *Boehmeria cylindrica*, Fountain (B). *Commandra richardsiana*, Fountain (B). *Rumex crispus*, Jackson (IU). **R. hastatulus**, Baldw. Gray Man. 8 ed. p. 571. Jackson (IU). Collected by Ray Jackson. *R. obtusifolius*, Jackson (IU), Washington (IU). *R. orbiculatus*, Fountain (B), Parke (B). *R. verticillatus*, Fountain (B), Hamilton (B), Lake (B, F). *Polygonum arifolium* v. *lentiforme*, Fountain (B). *P. coccineum*, Fountain (B). *P. hydropiperoides*, Fountain (B). *P. sagittatum*, Parke (B). *P. tenue*, LaPorte (B, F). *Chenopodium ambrosioides*, Fountain (B). *C. berlandieri*, Monroe (IU).

Amaranthus albus, Fountain (B). *A. graecizans*, LaPorte (B). *A. spinosus*, Fountain (B), Jackson (IU). *Mirabilis nyctaginea*, Fountain (B). *Phytolacca americana*, Fountain (B). *Claytonia virginica*, Parke (B). *Stellaria longifolia*, Jackson (IU), Parke (B). *Holosteum umbellatum*, Daviess (IU). *Silene stellata*, Morgan (IU). *Lychnis alba*, Cass (B), Fountain (B). *Saponaria officinalis*, Fountain (B). *Hydrastis canadensis*, Cass (B). *Cimicifuga racemosa*, Jackson (IU). *Delphinium tricorne*, Fountain (B). *Hepatica acutiloba*, Jackson (B). *Clematis pitcheri*, Fountain (B). *C. virginiana*, Fountain (B). *Ranunculus ambigens*, Fountain (B). *R. flabellaris*, Fountain (B). *R. sceleratus*, Fountain (B), Parke (B). *Thalictrum dioicum*, Parke (B). *Berberis japonica*, Wells (D).

Sassafras albidum, Cass (B), Jackson (B). *Dicentra cucullaria*, Jackson (IU), Shelby (B). *Lepidium virginicum*, Pulaski (B). *Thlaspi arvense*, Lake (B). *Sisymbrium officinale*, LaPorte (B, F). *Brassica nigra*, Parke (B). *Barbarea vulgaris* v. *arcuata*, Fountain (B), Porter (B). *Rorippa islandica* v. *fernaldiana*, Hancock (B). *R. sessiliflora*, Fountain (B). *R. sylvestris*, Parke (B). *Armoracea rusticana*, Clinton (B), Fountain (B). *Cardamine pennsylvanica*, Marion (B). *Arabis glabra*, Carroll (B). *Berteroa incana*, Monroe (IU). *Polanisia graveolens*, Fountain (B). *Saxifraga pennsylvanica*, Parke (B). *Mitella diphylla*, Owen (B). *Hydrangea arborescens* v. *oblonga*, Crawford (B). *Ribes americanum*, Fountain (B).

Physocarpus opulifolius, Bartholomew (IU), Wabash (B). *Crataegus phaenopyrum*, Elkhart (B). *Rubus occidentalis* f. *pallidus*, Jefferson (B). *Geum laciniatum*, Boone (B). *G. l.* v. *trichocarpum*, Fountain (B). *Filipendula rubra*, Fountain (B), Parke (B). *Agrimonia pubescens*, Washington (IU). *Prunus americana*, Jay (B, D). *Cassia hebecarpa*, DeKalb

(IU), Fountain (B). *C. marilandica,* Carroll (IU), Elkhart (IU), Hancock (B). *Gymnocladus dioica,* Fountain (B). *Melilotus alba,* Fountain (B). *Desmodium canadense,* Fountain (B). *Apios americana,* Fountain (B), LaPorte (B, F). *Strophostyles helveola,* Fountain (B), *Geranium carolinianum,* Lagrange (IU). *Polygala sanguinea,* Washington (IU). *Acalypha virginica,* Lagrange (IU). *Euphorbia carollata,* Fountain (B). *E. dentata,* Fountain (B). *E. heterophylla,* Fountain (B). *E. obtusata,* Fountain (B). *E. supina,* Fountain (B).

Rhus vernix, Parke (B), Wabash (B). *Ilex verticillata,* Decatur (B), Parke (B). *Acer negundo,* Fountain (B). *A. saccharinum,* Fountain (B). *Aesculus glabra,* Jackson (IU). **Rhamnus lanceolatus** v. **glabratus,** Gleason. Phytologia 4:25. 1952. Carroll (D), Cass (D), Dearborn (B,D), Franklin (D, NY), Henry (D), Lawrence (B, D), Randolph (B), Tippecanoe (B, D), Warren (D). *Vitis cinerea,* Fountain (B). *V. labrusca,* Monroe (IU). *Malva alcea,* Jackson (IU). *Hibiscus militaris,* Parke (B). *H. moscheutos,* Fountain (B). *H. trionum,* Morgan (IU). *Hypericum canadense,* LaPorte (B, F). *H. perforatum,* Fountain (B). *H. sphaerocarpum,* Fountain (B). *Lechea minor,* LaPorte (B, F). *Viola kitaibelliana* v. *rafinesquii,* Vermillion (B). *V. papilionacea,* Fountain (B). *V. pensylvanica,* Jackson (IU). *V. p.* f. *leiocarpa,* Parke (B). *V. sagittata,* Starke (B). *V. striata,* Shelby (B).

Ammania coccinea, Parke (B). *Decodon verticillatus* v. *laevigatus,* Fountain (B). *Ludwigia alternifolia,* Fountain (B), Parke (B). *L. palustris* v. *americana,* Fountain (B), Parke (B). *Oenothera pilosella,* Parke (B). *Circaea quadrisulcata* v. *canadensis,* Jackson (IU). *Sanicula canadensis,* Fountain (B), Kosciusko (B), Porter (B). *Chaerophyllum tainturieri,* Marion (B). *Osmorhiza longistylis,* Fountain (B). *Erigenia bulbosa,* Fountain (B), Jackson (IU). *Conium maculatum,* Jackson (IU). *Zizia aurea,* Carroll (B). *Cicuta maculata,* Fountain (B). *Sium suave,* Fountain (B), Monroe (IU), Parke (B). *Angelica atropurpurea,* Hamilton (B). *Oxypolis rigidior,* Fountain (B). *Pastinaca sativa,* DeKalb (IU). *Daucus carota,* Jackson (IU).

Monotropa hypopitys, LaPorte (B, F). *Samolus parviflorus,* Decatur (B), Fountain (B). *Lysimachia ciliata,* Fountain (B). *L. hybrida,* Carroll (IU). *L. nummularia,* Fountain (B), Hamilton (B), Jackson (IU). *L. thyrsiflora,* Fountain (B). *Anagallis arvensis,* Jackson (IU). *Fraxinus americana* v. *biltmoreana,* Jackson (B). *F. pennsylvanica,* Miami (B). *F. p.* v. *subintegerrima,* Miami (B). *Sabatia angularis,* Jackson (IU). *Swertia caroliniana,* LaPorte (F), Parke (B). *Apocynum sibiricum,* Fountain (B). *Asclepias exaltata,* Monroe (IU). *A. hirtella,* Jackson (IU). *A. incarnata,* Fountain (B), Jackson (IU). **A. incarnata f. albiflora,** Heller. Gray Man. 8 ed. p. 1173. Fountain (B). Collected by F. B. Buser. *A. syriaca,* DeKalb (IU). *A. tuberosa,* Jackson (IU). *A. verticillata,* Jackson (IU), Morgan (IU). *Ampelamus albidus,* Fountain (B), Morgan (IU).

Ipomoea lacunosa, Fountain (B). *I. pandurata,* Fountain (B), Jackson (IU), Monroe (IU). *Phlox maculata,* Fountain (B). *P. paniculata,* Fountain (B). *P. pilosa,* Parke (B). *Hydrophyllum appendiculatum,* Porter (F). *H. canadense,* Parke (B). *H. virginianum,* Monroe (IU). *Cynoglossum officinale,* Lake (B). *Hackelia virginianum,* Jackson (IU). *Mertensia virginica,* Fountain (B). *Lithospermum arvense,* Fountain (B). *L. canescens,* Starke (B). *Echium vulgare,* Lake (B). **E. v. f. roseum,** F. Zinn. Gray Man. 8 ed. p. 1200. Lake (B). Collected by F. A. Swink *Verbena stricta,* DeKalk (IU), Fountain (B). *V. urticifolia,* Bartholomew (IU). *Phyla lanceolata,* Fountain (B).

Scutellaria lateriflora, Fountain (B). *S. ovata* v. *versicolor,* Fountain (B), Jackson (IU), Parke (B). *Physostegia virginiana,* Fountain (B). *Stachys palustris* v. *homotrichia,* Fountain (B). *S. tenuifolia,* Fountain (B). *S. t.* v. *hispida,* Fountain (B). *Monarda fistulosa,* Fountain (B). *M. f.* v. *mollis,* Cass (B) *Pycnanthemum pilosum,* Parke (B). *P. virginianum,* Fountain (B). *Mentha arvensis,* Fountain (B). *Perilla frutescens* v. *crispa,* Montgomery (B), Parke (B). *Nicandra physaloides,* Fountain (B), Montgomery (B). *Physalis hereophylla,* Fountain (B). *Solanum carolinense,* Adams (IU). *S. nigrum,* Dearborn (B). *Verbascum blattaria,* Jackson (IU). *Scrophularia lanceolata,* DeKalb (IU). *Penstemon digitalis,* Jackson (IU). *Mimulus alatus,* DeKalb (IU). *M. ringens,* Fountain (B). *Gratiola virginiana,* Monroe (IU), Montgomery (B). *Lindernia anagallidea,* Lake (B, F). *Veronica peregrina,* Parke (B). *V. serpyllifolia,* Fountain (B), Parke (B). *Veronicastrum virginicum,* DeKalb (IU). *Pedicularis lanceolata,* Fountain (B), Parke (B).

Campsis radicans, Fountain (B). *Orobanche uniflora,* Starke (B). *Ruellia caroliniensis,* Jackson (IU). *R. strepens* f. *cleistantha,* Fountain (B). *Justicia americana,* Bartholomew (IU). *Phryma leptostachya,* Jackson (IU), Porter (B). *Plantago lanceolata,* Jackson (IU). **Houstonia minima,** Beck. Gray Man. 8 ed. p. 1329. Fountain (B). Collected by Jack McCormick. *Cephalanthus occidentalis,* Fountain (B). *Diodia teres* v. *setifera,* Fountain (B). *Galium aparine,* Parke (B). *G. asprellum,* Fountain (B). *G. obtusum,* Fountain (B), Parke (B). *G. tinctorium,* Kosciusko (B). *Viburnum dentatum* v. *deamii,* Decatur (B), Parke (B). *V. lentago,* Miami (B). *Triosteum perfoliatum,* Parke (B). *T. aurantiacum* v. *illinoense,* Parke (B). *Lonicera japonica,* Decatur (B). *Dipsacus sylvestris,* Parke (B). *Campanula americana* v. *illinoensis,* Lake (B). *C. aparinoides,* Fountain (B).

Eupatorium coelestinum, Fountain (B). *E. sessilifolium,* Parke (B). *Liatris pycnostachya,* Greene (IU). *Solidago caesia* f. *axillaris,* Brown (B), Clark (B), Crawford (B), Decatur (B), Dubois (B), Hamilton (B), Hancock (B), Harrison (B), Jasper (B), Jefferson (B), Lake (B), Marion (B), Monroe (B), Morgan (B), Steuben (B), White (B). *S. canadensis* v. *gilvocanescens,* Wabash (B). *S. gigantea* v. *leiophylla,* Cass (B). **S. graminifolia v. polycephala Fern.** Gray Man. 8 ed. p. 1412. Ripley (B). Collected by Delzie Demaree. *S. juncea,* Jackson (IU). *S. riddellii,* Cass (B). *S. uliginosa* v. *linoides,* Cass (B). *Boltonia latisquama* v. *recognita,* Fountain (B). *Aster macrophyllus,* Decatur (B). *A. prenanthoides,* Crawford (B). *A. sagittifolius,* Decatur (B). *A. simplex* v. *ramosissima,* Decatur (B). *Antennaria neglecta,* Montgomery (B). *Gnaphalium purpureum,* Fountain (B). *Silphium perfoliatum,* Bartholomew (IU), Fountain (B). *Ambrosia artemisifolia* v. *elatior* f. *villosa,* Dearborn (B). *A.*

bidentata, Fountain (B). *A. trifida*, Fountain (B). *Heliopsis helianthoides*, Bartholomew (IU), DeKalb (IU), Jackson (IU), Morgan (IU).

Rudbeckia hirta, Fountain (B). *R. laciniata*, Fountain (B), Morgan (IU). *R. triloba*, Posey (IU). *Helianthus decapetalus*, Fountain (B). *H. divaricatus*, Parke (B). *H. maximiliani*, Monroe (IU). *H. microcephalus*, Bartholomew (IU). *H. tuberosus*, Dearborn (B). *Actinomeris alternifolia*, Lake (B, F). *Verbesina helianthoides*, Parke (B). *Coreopsis tripteris*, Wabash (B). *Bidens comosa*, Decatur (B). **B. connata** v. **anomala**, Farw. Gray Man. 8 ed. p. 1503. Lake (B, F). Collected by F. A. Swink. *B. coronata*, Fountain (B). *B. frondosa*, Fountain (B). *Galinsoga ciliata*, Morgan (IU). *Helenium nudiflorum*, Kosciusko (B). *Anthemis cotula*, Jackson (IU). *Chrysanthemum leucanthemum* v. *pinnatifidum*, Fountain (B). *Cacalia atriplicifolia*, Bartholomew (IU), DeKalb (IU). *C. suaveolens*, Fountain (B). *Senecio pauperculus*, Pulaski (B). *Cirsium arvense*, Jackson (IU). *C. discolor*, Dearborn (B). *C. muticum*, Parke (B), Wabash (B). *Tragopogon major*, Jackson (IU). *T. porrifolius*, Bartholomew (IU). *Taraxacum erythrospermum*, Starke (B). *Sonchus arvensis* v. *glabrescens*, Fulton (B). *Prenanthes racemosa*, Cass (B). *Hieracium longipilum*, Kosciusko (B), LaPorte (B, F). *H. scabrum*, Parke (B).

State Flora Committee: CHARLES C. DEAM, *Chairman*
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A Taxonomic Study of Sixty Pollen Grains Collected by Honey Bees

Howard R. Youse, DePauw University

Pollen may enter the hives of honey bees in three ways. The major source of pollen in the hive is collected by pollen-collecting bees. Honey bees collect the pollen grains from the anthers and pack them into small balls on their hind legs. These balls or pellets of pollen are then carried to the hive where they are stored or used as food. Bees may become dusted with pollen in their quest for nectar, and thus they return to the hive covered with pollen. It has been observed many times that these bees are always cleaned up before they return to the field; thus they contribute some to the pollen supply. In addition, pollen grains are abundant in nectar, and hence the bees naturally collect some pollen as they collect nectar.

From a taxonomic study of hive pollen one may determine the sources of honey as well as the plants visited for pollen. It was as a result of a study of major pollen sources for honey bees in Indiana that the author became interested in the taxonomic study of the pollen grains.

In order to study the pollen grains collected by honey bees one may collect ripe anthers from the flowers on which honey bees are observed working. This is often a time consuming task, and the supply of pollen obtained is very small. In this case, however, the source is never questioned. If one desires larger quantities of pollen, one can secure it by means of a pollen trap placed in front of the hive entrance so that the pellets are removed from the bees as they enter the hive. The identification of such pollen then becomes some problem.

The process of handling the pollen collected in either manner should be the same. In the present study the anthers or pellets were desiccated in a calcium chloride drier and then stored in gelatine capsules or air tight glass vials until ready for critical study.

The descriptions of the pollen grains given in the following section were obtained from slides prepared in the following manner. Desiccated pollen was placed on a slide and several drops of tertiary butyl alcohol were added to soften the grains. The slide was then heated gently and additional drops of tertiary butyl alcohol added to remove any oils that might be present on the grains. A drop of liquid glycerine jelly to which had been added a small amount of basic fushin was added and a cover slip applied. The size of the grains is based on an average of ten grains.

Photomicrographs of the pollen grains which appear in Plate A were made with a Bausch and Lomb microscope, camera, and lamp. Eastman Panatomic-X 3¼x4¼ sheet film was used, and it was developed in D-76. The grains were photographed at approximately 500 magnifications.

The morphological characters that are of greatest value in the identification of pollen grains are the number and arrangement of the furrows and pores, the sculpturing of the exine, and the size and shape of the grains (Zander, 1941 and Erdtman, 1943). The size and shape of the

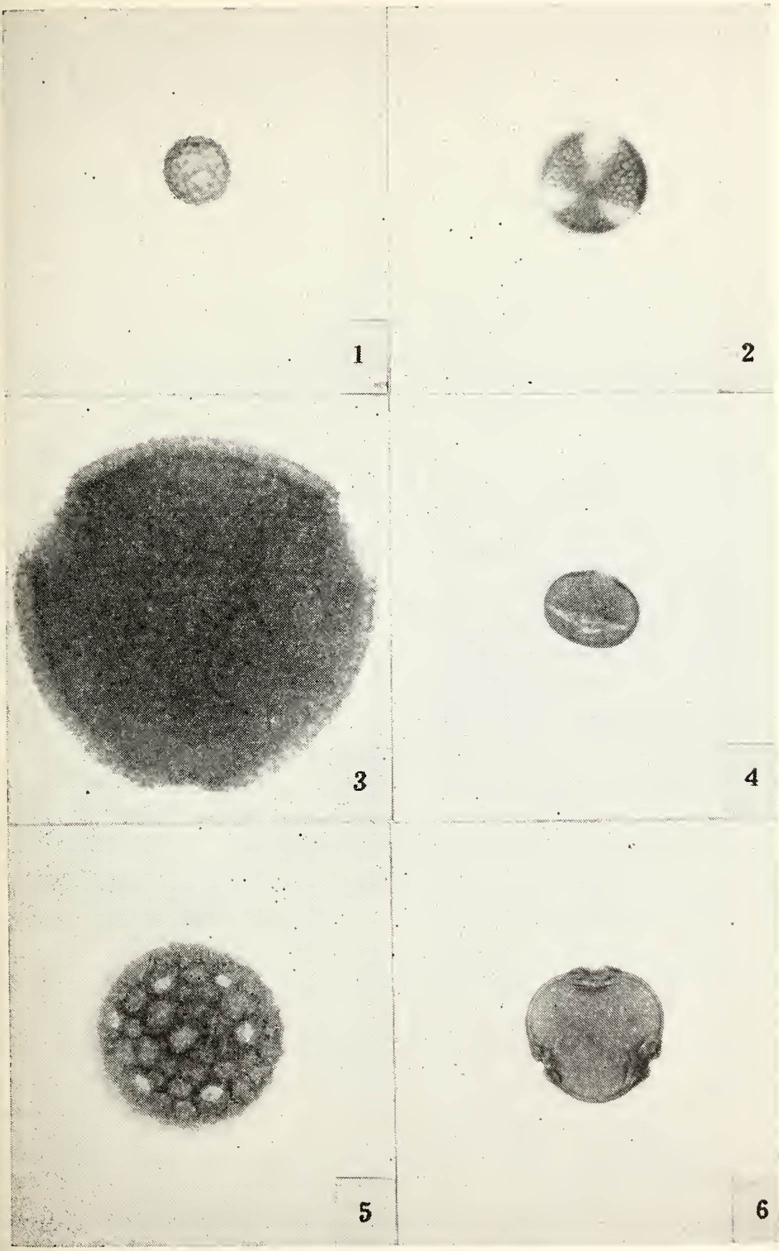

Plate A. Six pollen grains frequently collected by honey bees.

Fig. 1. *Ambrosia elatior* L. x500

Fig. 2. *Brassica nigra* (L.) Koch. x500

Fig. 3. *Geranium maculatum* L. x500

Fig. 4. *Melilotus alba* Desr. x500

Fig. 5. *Polygonum Persicaria* L. x500

Fig. 6. *Tilia americana* L. x500

grains are helpful, but they may be subject to great variation in some genera. In addition they vary somewhat due to the method in which the grains are processed. Since pollen grains of the same or closely related species tend to be alike if the environmental factors are uniform (Wodehouse, 1935), it usually is not practical to attempt to identify hive pollen more than to genera.

A brief description of sixty pollen grains collected by honey bees in Indiana follows. The sources are in alphabetical order as follows:

Acer saccharum Marsh. (Sugar Maple) Size: 33 microns; Shape: Oblately spheroidal; Furrows: 3 wide, conspicuous; Sculpturing: Exine finely granular.

Aesculus glabra Willd. (Ohio Buckeye) Size: 20 microns; Shape: Spheroidal; Pores: 3; Sculpturing: Exine granular.

Althaea rosea (L.) Cav. (Hollyhock) Size: 116 microns; Shape: Spheroidal; Pores: Numerous, but not conspicuous; Sculpturing: Exine about 5 microns thick, covered with sharp, conical spines 9 microns long.

Ambrosia elatior L. (Common Ragweed) Size: 18 microns; Shape: Spheroidal; Pores: 3; Sculpturing: Exine covered with short, reduced spines about 2 to 3 microns apart.

Apocynum cannabinum L. (Hemp Dogbane) Size: Tetrad 25 microns; Shape: Tetrad; Pores: 0; Sculpturing: Exine finely granular.

Arctium minus (Hill) Bernh. (Common Burdock) Size: 41 microns; Shape: Spheroidal; Pores: 3, conspicuous; Sculpturing: Exine thick with short, conical spines.

Asparagus officinalis L. (Garden Asparagus) Size: 25 microns x 21 microns; Shape: Ellipsoidal; Furrows: 1; Sculpturing: Exine smooth.

Aster pilosus Willd. (Heath Aster) Size: 22 microns; Shape: Spheroidal; Pores: 3; Sculpturing: Exine spines about 3 microns long, texture finely granular.

Berberis Thunbergii DC. (Japanese Barberry) Size: 38 microns; Shape: Oblately spheroidal; Furrows: 3, spiral or unequally spaced; Sculpturing: Exine granular.

Brassica nigra (L.) Koch. (Black Mustard) Size: 30 microns; Shape: Spheroidal; Furrows: 3; Sculpturing: Exine heavily reticulate.

Campanula americana L. (Tall Bellflower) Size: 41 microns; Shape: Spheroidal; Pores: 3 to 6, conspicuous; Sculpturing: Exine thick and reticulate.

Catalpa bignonioides Walt. (Catalpa) Size: Tetrad 58 microns; Shape: Tetrad; Pores: 0; Sculpturing: Exine thick and reticulate.

Cirsium arvense (L.) Scop. (Canada Thistle) Size: 42 microns; Shape: Spheroidal; Pores: 3, conspicuous; Sculpturing: Exine thick, with high ridges and lacunae, covered with long, sharp spines over 3 microns in length.

Claytonia virginica L. (Virginia Spring Beauty) Size: 55 microns; Shape: Spheroidal; Furrows: 3, conspicuous; Sculpturing: Exine, thick, granular.

Cornus florida L. (Flowering Dogwood) Size: 22 microns; Shape: Oblately spheroidal; Pores: 3, conspicuous; Sculpturing: Exine granular.

Corylus americana Walt. (American Hazelnut) Size: 20 microns; Shape: Oblately spheroidal; Pores: 3, conspicuous; Sculpturing: Exine smooth, slightly expanded at the pores.

Cucumis sativus L. (Cucumber) Size: 50 microns; Shape: Oblately spheroidal; Pores: 3, conspicuous; Sculpturing: Exine smooth.

Cucurbita Pepo L. (Pumpkin) Size: 136 microns; Shape: Spheroidal; Pores: 4 or more, large conspicuous, scattered over the surface of the grain; Sculpturing: Exine covered with large spines.

Dianthera americana L. (Dense-flowered Water Willow) Size: 38 microns x 23 microns; Shape: Ellipsoidal; Pores: 3, only one or two appearing in any view; Sculpturing: Exine finely granular.

Dipsacus sylvestris Huds. (Common Teasel) Size: 86 microns; Shape: Oblately spheroidal; Pores: 3, conspicuous; Sculpturing: Exine with short, conical spines and irregular branching at the pores.

Fagopyrum esculentum Moench. (Buckwheat) Size: 58 microns x 42 microns; Shape: Ellipsoidal; Pores: 3, only one or two appearing in any view; Sculpturing: Exine thick, coarse, granular.

Fragaria virginiana Duchesne. (Virginia Strawberry) Size: 23 microns; Shape: Angular; Furrows: 3; Sculpturing: Exine granular, granules appearing in rows.

Geranium maculatum L. (Wild Geranium) Size: 91 microns; Shape: Oblately spheroidal; Pores: 3, conspicuous; Sculpturing: Exine, thick, palisade-like.

Grossularia Cynostabi (L.) Mill. (Pasture Gooseberry) Size: 25 microns; Shape: Spheroidal; Pores: 4 or more, conspicuous; Sculpturing: Exine smooth.

Helianthus annuus L. (Common Sunflower) Size: 28 microns; Shape: Spheroidal; Pores: 3, conspicuous; Sculpturing: Exine thick with spines about 5 microns long.

Hydrophyllum appendiculatum Michx. (Appendated Waterleaf) Size: 18 microns; Shape: Oblately spheroidal; Furrows: 3, wide, conspicuous; Sculpturing: Exine smooth, thin.

Ipomoea purpurea (L.) Roth. (Common Morning-glory) Size: 92 microns; Shape: Spheroidal; Pores: Numerous, conspicuous; Sculpturing: Exine thick, covered with sharp, conical spines enlarged at the base.

Leonurus Cardiaca L. (Common Motherwort) Size: 18 microns; Shape: Spheroidal; Pores: 3, conspicuous; Sculpturing: Exine smooth.

Liriodendron Tulipifera L. (Tulip Tree) Size: 66 microns x 40 microns; Shape: Ellipsoidal; Furrows: 1; Sculpturing: Exine pitted, with conspicuous warts.

Lonicera japonica Thumb. (Japanese Honeysuckle) Size: 50 microns; Shape: Oblately spheroidal; Pores: 3, conspicuous; Sculpturing: Exine covered with small, sharp spines about 2-3 microns long.

Malus pumila L. (Common Apple) Size: 38 microns; Shape: Angular, many abortive grains and irregular grains in a pollen sample; Furrows: 3; Sculpturing: Exine granular.

Medicago sativa L. (Alfalfa) Size: 25 microns x 21 microns; Shape: Ellipsoidal; Furrows: 3, one or two appearing in any view; Sculpturing: Exine granular.

Melilotus alba Desr. (White Sweetclover) Size: 25 microns x 21 microns; Shape: Ellipsoidal; Furrows: 3, one or two appearing in any view; Sculpturing: Exine granular.

Mentha piperita L. (Peppermint) Size: 25 microns x 22 microns; Shape: Ellipsoidal; Furrows: 6, not conspicuous; Sculpturing: Exine smooth.

Monardia fistulosa L. (Wild Bergamot) Size: 49 microns x 38 microns; Shape: Ellipsoidal; Furrows: 6, conspicuous; Sculpturing: Exine smooth.

Nepeta Cataria L. (Catnip) Size: 33 microns x 28 microns; Shape: Ellipsoidal; Furrows: 6, conspicuous; Sculpturing: Exine smooth.

Parthenocissus quinquefolia (L.) Planch. (Virginia Creeper) Size: 33 microns; Shape: Spheroidal or nearly so; Pores: 3; Sculpturing: Exine granular.

Polanisia graveolens Raf. (Clammyweed) Size: 20 microns; Shape: Oblately spheroidal; Furrows: 3, narrow; Sculpturing: Exine granular.

Polygonum Persicaria L. (Lady's Thumb) Size: 58 microns; Shape: Spheroidal; Pores: Numerous; Sculpturing: Exine thick, reticulate, with high vertical ridges.

Populus deltoides Michx. (Cottonwood) Size: 27 microns; Shape: Spheroidal; Pores and Furrows: 0; Sculpturing: Exine granular.

Prunus serotina Ehrh. (Black Cherry) Size: 25 microns; Shape: Angular, many abortive and irregular grains in pollen sample; Furrows: 3; Sculpturing: Exine granular.

Pychanthemum flexuosum (Walt.) BSP. (Slender Mountain-mint) Size: 25 microns x 17 microns; Shape: Ellipsoidal; Furrows: 6, not conspicuous; Sculpturing: Exine smooth.

Ranunculus recurvatus Poir. (Hooked Buttercup) Size: 40 microns; Shape: Spheroidal; Furrows: 3, not conspicuous; Sculpturing: Exine granular.

Rhamnus Frangula L. (Glossy Buckthorn) Size: 20 microns; Shape: Oblately spheroidal; Pores: 3, conspicuous; Sculpturing: Exine finely reticulate.

Rhus aromatica Ati. (Fragrant Sumac) Size: 30 microns; Shape: Spheroidal; Furrows: 3; Sculpturing: Exine granular.

Robinia Pseudo-Acacia L. (Black Locust) Size: 30 microns; Shape: Oblately spheroidal; Furrows: 3, narrow; Sculpturing: Exine smooth.

Rosa setigera var. tomentosa T. & G. (Prairie Rose) Size: 30 microns; Shape: Angular; Furrows: 3; Sculpturing: Exine granular.

Rubus occidentalis L. (Common Blackcap Raspberry) Size: 25 microns; Shape: Angular; Furrows: 3; Sculpturing: Exine granular.

Salix discolor Muhl. (Pussy Willow) Size: 18 microns; Shape: Spheroidal; Furrows: 3; Sculpturing: Exine heavily reticulate.

Sambucus canadensis L. (Elderberry) Size: 17 microns; Shape: Spheroidal; Pores: 3; Sculpturing: Exine smooth.

Sassafras albidum (Nutt.) Nees. (Sassafras) Size: 42 microns; Shape: Spheroidal; Pores and Furrows: 0; Sculpturing: Exine covered with short conical spines.

Solidago nemoralis Ait. (Old-field Goldenrod) Size: 22 microns; Shape: Spheroidal; Pores: 3; Sculpturing: Exine spines about 3 microns long, texture finely granular.

Staphylea trifolia L. (American Bladdernut) Size: 42 microns; Shape: Oblately spheroidal; Pores: 3, furrows conspicuous; Sculpturing: Exine reticulate.

Symphoricarpos orbiculatus Moench. (Coralberry) Size: 38 microns; Shape: Oblately spheroidal; Pores: 3; Sculpturing: Exine smooth.

Taraxacum paulstre var. vulgare (Lam.) Fern. (Dandelion) Size: 35 microns; Shape: Spheroidal; Pores: 3; Sculpturing: Exine thick, with high ridges and lacunae and sharp conical spines 2 microns or under in length.

Tilia americana L. (American Linden, Basswood) Size: 36 microns; Shape: oblately spheroidal; Pores: 3, sunken in the surface of the grain; Sculpturing: Exine reticulate.

Trifolium hybridum L. (Alsike Clover) Size: 25 microns x 21 microns; Shape: Ellipsoidal; Furrows: 3, one or two appearing in any view; Sculpturing: Exine granular.

Ulmus americana L. (American Elm) Size: 28 microns; Shape: Spheroidal; Pores: 3-6; Sculpturing: Exine smooth but with reticulate appearance due to underlying layers.

Vitis aestivalis Michx. (Summer Grape) Size: 16 microns; Shape: Oblately spheroidal; Pores: 3, slightly sunken in the exine; Sculpturing: Exine smooth.

Zea Mays L. (Corn) Size: 91 microns; Shape: Spheroidal or nearly so; Pores: 1; Sculpturing: Exine granular.

The following key was prepared as an aid to the study of pollen grains brought into the hive by honey bees in Indiana. It is based on photomicrographs and the descriptions of pollen in the above section. It is therefore limited to this group of plants and closely related species in each genus.

1.	Grains in tetrads	2
	Grains single	3
2.	Exine finely granular, tetrad 25 microns	*Apocynum cannabinum*
	Exine thick, reticulate, tetrad 58 microns	*Catalpa bignonioides*
3.	Pores and furrows absent	4
	Pores or furrows present	5
4.	Exine covered with short spines, grains 42 microns	*Sassafras albidum*
	Exine granular, grains 27 microns	*Populus deltoides*
5.	Germinal apparatus consisting of a single furrow or pore	6
	Germinal apparatus consisting of more than one furrow or pore	8
6.	Pores absent, furrows one	7
	Pores one, furrows absent, grains 91 microns	*Zea Mays*
7.	Exine smooth, grains ellipsoidal, grains 25 microns x 21 microns	*Asparagus officinalis*
	Exine warty, rough, boat-shaped, grains 66 microns x 40 microns	*Liriodendron Tulipifera*
8.	Exine spiny	9
	Exine smooth, granular, or reticulate	19
9.	Grains large, over 75 microns	10
	Grains small, under 60 microns	13
10.	Grains spheroidal, spines long	11
	Grains oblately spheroidal, spines short, grains 86 microns	*Dipsacus sylvestris*
11.	Spines straight at the base, grains over 100 microns	12
	Spines bulbous at the base, grains 92 microns	*Ipomoea purpurea*

12. Pores conspicuous, spines scattered, grains 136 microns...... *Cucurbita Pepo*
Pores not conspicuous, spines densely covering the exine, grains 116 microns.................. *Althaea rosea*

13. Grains spheroidal 14
Grains oblately spheroidal, grains 50 microns............ *Lonicera japonica*

14. Exine with high ridges and lacunae.. 15
Ridges and lacunae absent on exine.. 16

15. Spines sharp, over 3 microns in length, grains 42 microns.... *Cirsium arvense*
Spines sharp, conical, 2 microns or under in length, grains 35 microns.................... *Taraxacum palustre*

16. Pores and furrows less conspicuous, grains under 30 microns.............. 17
Pores and furrows very conspicuous, grains 41 microns....... *Arctium minus*

17. Spines long, sharp, grains over 20 microns............................... 18
Spines short, reduced, grains 18 microns.................. *Ambrosia elatior*

18. Spines 5 microns or longer, grains 28 microns............ *Helianthus annuus*
Spines 3 microns or less, grains 22 microns.................. *Aster pilosus*
Solidago nemoralis

19. Grains angular, irregular, often abortive................................ 20
Grains ellipsoidal 21
Grains spheroidal or oblately spheroidal.................................. 25

20. Exine granular, granules appearing in rows, grains 23 microns...................... *Fragaria virginiana*
Exine granular, granules appearing in no definite pattern, grains over 25 microns................ *Malus pumila*
Rosa setigera
Prunus serotina
Rubus occidentalis

21. Pores present 22
Pores absent 23

22. Exine thick, coarse, granular, grains 58 microns x 42 microns................ *Fagopyrum esculentum*
Exine finely granular, grains 38 microns x 23 microns... *Dianthera americana*

23. Furrows 6, exine smooth.. 24
Furrows 3, exine granular, grains 25 microns x 23 microns............................ *Melilotus alba*
Medicago sativa
Trifolium hybridum

24. Furrows conspicuous, grains around 35 microns or larger..... *Nepeta Cataria*
Monardia fistulosa
Furrows not conspicuous, grains around 25 microns or smaller...................... *Mentha piperita*
Pychanthemum flexuosum

25. Pores absent, furrows 3.. 26
Pores 3 or more... 36

26. Grains oblately spheroidal... 27
Grains spheroidal 31

27. Grains over 30 microns... 28
Grains under 20 microns... 30

28. Furrows equally spaced, grains under 35 microns.......................... 29
Furrows spiral or unequally spaced, grains 38 microns... *Berberis Thunbergii*

29. Furrows wide and conspicuous, exine granular, grains 33 microns................... *Acer saccharum*
Furrows narrow, less conspicuous, exine smooth, grains 30 microns................ *Robinia Pseudo-Acacia*

30. Furrows wide, conspicuous, exine smooth, grains 18 microns.............. *Hydrophyllum appendiculatum*

Furrows narrow, less conspicuous,
exine granular, grains 20 microns................*Polanisia graveolens*

31. Exine heavily reticulate.. 32
Exine granular or smooth.. 33

32. Grains 30 microns ....*Brassica nigra*
Grains 18 microns ....*Salix discolor*

33. Grains 40 microns or over 34
Grains 30 microns or under 35

34. Furrows very conspicuous, grains 55 microns............*Claytonia virginica*
Furrows not conspicuous, grains 40 microns.........*Ranunculus recurvatus*

35. Exine granular, grains 30 microns.......................*Rhus aromatica*
Exine smooth, grains 18 microns.....................*Leonurus Cardiaca*

36. Pores usually 4 or more.. 37
Pores 3 40

37. Exine thick, reticulate, grains 40 microns or over....................... 38
Exine thin, smooth, grains 30 microns or under........................ 39

38. Exine with high, vertical ridges, grains 58 microns....*Polygonum Persicaria*
Exine with no vertical ridges, grains 41 microns......*Campanula americana*

39. Exine reticular appearance, grains 28 microns............*Ulmus americana*
Exine smooth, grains 25 microns....................*Grossularia Cynosbati*

40. Grains 40 microns or larger 41
Grains 35 microns or less 43

41. Exine smooth or reticulate, grains smaller............................. 42
Exine thick, palisade-like, grains 91 microns..........*Geranium maculatum*

42. Furrows absent, exine smooth, grains 50 microns..........*Cucumis sativus*
Furrows present, exine reticulate, grains 42 microns......*Staphylea trifolia*

43. Pores sunken in the exine... 44
Pores on the surface of the exine....................................... 45

44. Exine reticulate, grains 36 microns.......................*Tilia americana*
Exine smooth, grains 16 microns.........................*Vitis aestivalis*

45. Furrows absent or not conspicuous....................................... 46
Furrows present and conspicuous... 48

46. Grains about 20 microns... 47
Grains 38 microns..........................*Symphoricarpos orbiculatus*

47. Exine smooth, slightly raised at the pore................*Corylus americana*
Exine finely reticulate, not raised at the pore............*Rhamnus Frangula*

48. Grains spheroidal 49
Grains oblately spheroidal, grains 22 microns...............*Cornus florida*

49. Exine granular, grains over 20 microns................................. 50
Exine smooth, grains 17 microns...................*Sambucus canadensis*

50. Grains 33 microns.......................................*Aesculus glabra*
Grains 20 microns ....*Parthenocissus quinquefolia*

These investigations indicate that one can determine the plant genera that bees visit by a taxonomic study of hive pollen. Since honey bees are relatively constant in their collecting, usually only one kind of pollen is found in each pellet. In some cases where pollen grains of related genera are quite similar such as is found in the Rosaceae and Leguminosae, the time of flowering may be helpful. In the most difficult cases direct observations of bees working on the flowers must be made. In all cases the latter is the most dependable as far as determining the actual plant source.

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Studies in Indiana Bryophytes X

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The introductory remarks for this study are comparable to those of number eight in the series. The writer is indebted to the Indiana Academy of Science and the Graduate Council of DePauw University for research grants and to the State University of Iowa for three honoraria. The latter were used during the summers of 1950, 1951, and 1952 at the Iowa Lakeside Laboratory, in research on Indiana mosses under the leadership and generous counsel of Dr. H. S. Conard. The author in this way wishes to express deep appreciation to Dr. Conard.

LESKEACEAE (continued)

Key to the genera in Leskeaceae[1]

1. Stem leaves with paraphyllia-like filaments at base........*Helodium*
1. Stem leaves without paraphyllia-like filaments at base............2.
    2. Paraphyllia on stems and branches more or less abundant.*Thuidium*
    2. Paraphyllia on stems and branches occasional or absent........3.
        3. Plants light to glaucous green; leaf margins usually ciliate or spinose-dentate ....4.
            4. Costa single, reaching middle of leaf, or short, or forking; paraphyllia present ....*Thelia*
            4. Costa short or lacking; paraphyllia absent.......*Myurella*
        3. Plants green, not glaucous; leaf margins not ciliate or spinose-dentate ....4.
            4. Leaf apices colorless...................................5.
                5. Costa extending to middle of leaf...........*Lindbergia*
                5. Costa ending just below apex..............*Anomodon*
            4. Leaf apices green.......................................5.
                5. Marginal cells bulging................*Haplohymenium*
                5. Marginal cells not bulging.........................6.
                    6. Costa pellucid ....*Anomodon*
                    6. Costa not pellucid........................*Leskea*

Subfamily ANOMODONTEAE

Plants medium to moderately large in size; paraphyllia usually lacking; leaf cells small, rounded to subhexagonal, densely papillose; capsules erect, symmetric or nearly so; peristome of 16 slender teeth; inner peristome of a low basal membrane, frequently with short linear segments.

Key to the genera of Anomodonteae

Plants very slender; leaves brittle, apices frequently broken from dry blades; costa extending to the middle of the leaf; marginal cells of leaf bulging ....*Haplohymenium*

Plants somewhat robust; leaves not conspicuously brittle; costa ending in or just below apex; marginal cells not bulging...........*Anomodon*

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[1] The study of the subfamily Thuidieae, treating the genera *Helodium* and *Thuidium*, was published in Proc. Ind. Acad. Sci. **61**:106-110. 1952.

ANOMODON

Plants in dense mats or cushions, commonly dark green; branches sometimes flagelliform; paraphyllia lacking; leaves close, usually in 5 rows; lingulate from an ovate or oblong clasping base; margins plane and entire; costa strong, pellucid, smooth, usually ending just below apex; median cells rounded-hexagonal, densely papillose on both sides; capsules erect, symmetric, oblong-cylindric; peristome teeth linear-lanceolate; operculum conic to rostrate.

Key to species of Anomodon

1. Leaves slenderly acuminate, ending in a hair point...... *A. rostratus*
1. Leaves not ending in a hair point............................2.
    2. Branches frequently attenuate to flagelliform; leaves usually apiculate and toothed at the apex.................. *A. attenuatus*
    2. Branches not attenuate or flagelliform; leaf apices rounded-obtuse and entire.. *A. minor*

A. attenuatus (Hedw.) Hueben. (Figs. 1-3.) Bartholomew, Benton, Blackford, Boone, Brown, Carroll, Cass, Clark, Clinton, Crawford, Daviess, Dearborn, Delaware, Dubois, Elkhart, Fayette, Fountain, Gibson, Grant, Harrison, Hendricks, Henry, Jackson, Jasper, Jay, Jefferson, Jennings, Johnson, Knox, Kosciusko, Lawrence, Madison, Martin, Miami, Monroe, Montgomery, Morgan, Noble, Orange, Owen, Parke, Perry, Pike, Porter, Posey, Pulaski, Putnam, Randolph, Ripley, Shelby, Spencer, Steuben, Union, Vermillion, Wabash, Warren, Warrick, Washington, Wayne, Wells, and White counties.

A. minor (Beauv.) Lindb. (Figs. 4-5.) Bartholomew, Benton, Brown, Cass, Clinton, Dearborn, Decatur, Delaware, Fayette, Fountain, Grant, Harrison, Hendricks, Jefferson, Jennings, Knox, Kosciusko, Lake, LaPorte, Lawrence, Madison, Martin, Monroe, Montgomery, Noble, Owen, Parke, Perry, Pike, Putnam, Randolph, Ripley, Shelby, Switzerland, Warren, and Wayne counties.

A. rostratus (Hedw.) Schimp. (Figs. 6-8.) Benton, Blackford, Brown, Cass, Clark, Crawford, Daviess, Dearborn, Delaware, Fayette, Grant, Harrison, Henry, Huntington, Jay, Jefferson, Jennings, Lake, Lawrence, Madison, Martin, Monroe, Montgomery, Noble, Owen, Parke, Perry, Porter, Posey, Putnam, Randolph, Ripley, Steuben, Union, Warren, Washington, Wayne, Wells, and White counties.

HAPLOHYMENIUM

Plants very slender, in loose mats, dull green; stems pinnately branched; leaves appressed when dry, squarrose-spreading when moist, very brittle, concave, subclasping, lanceolate from an ovate base, apices rounded, obtuse, or acute, often apiculate, very often broken from dried leaves; narrowly costate to about the middle of the leaf, costa papillose on back; cells of leaf somewhat translucent, turgid, bearing several large papillae on each face, rounded-hexagonal in upper portion of blade; marginal cells bulging and papillate; capsule unknown.

H. triste (Cesati) Kindb. (Fig. 9.) Hendricks, Jefferson, Jennings, Madison, Monroe, Montgomery, Morgan, Parke, Perry, Putnam, and Steuben counties.

Subfamily LESKEAE

Stems pinnately or subpinnately branched; leaves appressed when dry and erect-spreading to spreading when moist; capsules erect, usually straight, occasionally slightly curved; peristome perfect, with inner peristome short, rudimentary, or absent.

Key to the genera of Leskeae

Leaf apices frequently colorless; papillae on leaf cells single, large..*Lindbergia*

Leaf apices not colorless; papillae on leaf cells one to several, small.*Leskea*

LESKEA

Plants small to medium-sized, growing in mats or spreading tufts; stems prostrate, pinnately to subpinnately branched; paraphyllia sometimes present; leaves concave, costate, usually papillose, ovate to ovate-lanceolate, apices acute, acuminate, or obtuse, margins commonly entire, occasionally serrulate in apices; capsules straight or slightly curved, subcylindric or oblong-cylindric; peristome double, outer of 16 linear-lanceolate teeth and inner of 16 segments extending from a basal membrane 1/5-1/4 the length of the teeth; operculum conic, obtuse, acute, or apiculate.

Key to species of Leskea

1. Leaves of stems more than twice as long as wide........*L. polycarpa*[2]
1. Leaves of stems less than twice as long as wide...................2.
   2. Leaves symmetric, lightly biplicate; margins frequently revolute .... *L. gracilescens*
   2. Leaves not symmetric, not or faintly plicate; margins plane.. *L. obscura*

L. gracilescens Hedw. (Fig. 10.) Bartholomew, Benton, Blackford, Boone, Carroll, Cass, Clark, Clay, Clinton, Crawford, Daviess, Dearborn, Decatur, Delaware, Dubois, Fayette, Fountain, Gibson, Greene, Harrison, Hendricks, Henry, Jasper, Jay, Jefferson, Jennings, Johnson, Knox, Kosciusko, Lagrange, Lake, Lawrence, Madison, Marion, Marshall, Martin, Miami, Monroe, Montgomery, Newton, Noble, Orange, Owen, Parke, Perry, Porter, Posey, Pulaski, Putnam, Randolph, Ripley, Rush, Scott, Shelby, Spencer, Starke, Sullivan, Switzerland, Tippecanoe, Tipton, Union, Vanderburgh, Vermillion, Wabash, Warren, Warrick, Wayne, Wells, White, and Whitley counties.

L. obscura Hedw. (Fig. 11.) Clark, Clinton, Harrison, Jasper, Jay, Jefferson, Knox, Kosciusko, Parke, Perry, Posey, Pulaski, Putnam, Ripley, Saint Joseph, Scott, and White counties.

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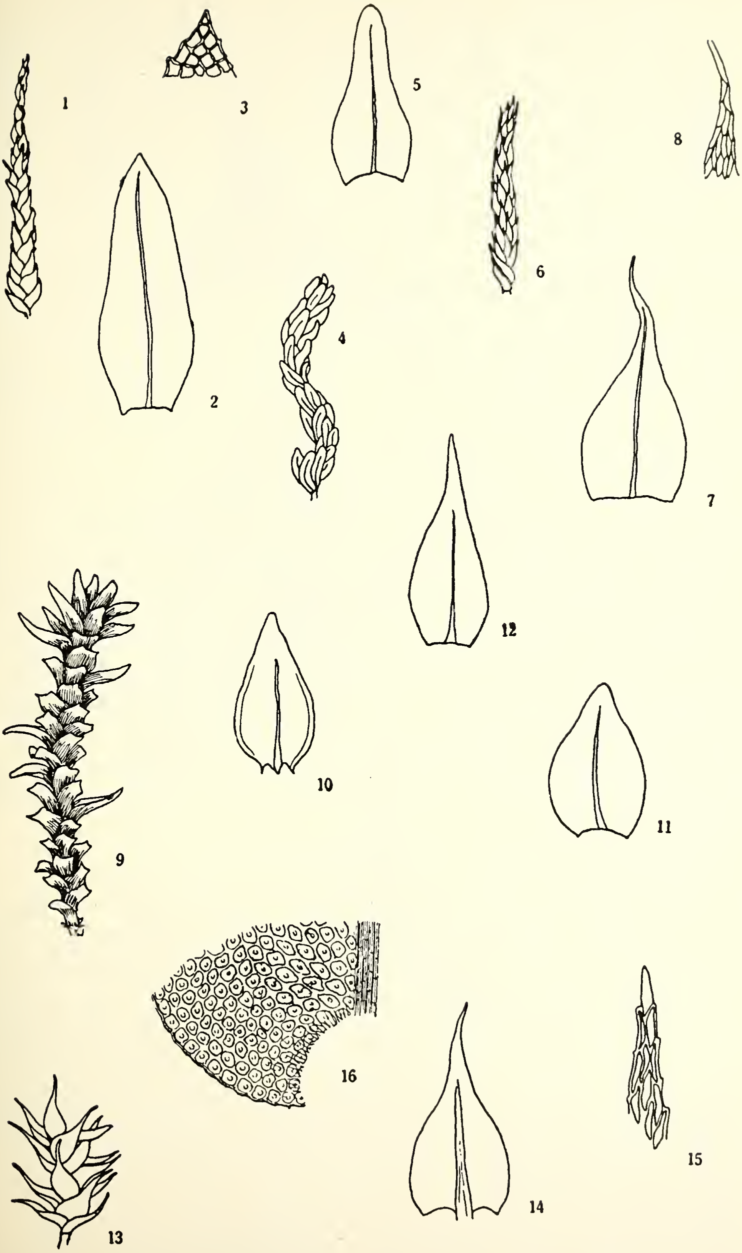
[2] *Leskea polycarpa* Hedw. not yet reported from Indiana.

PLATE A



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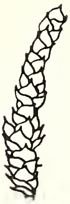
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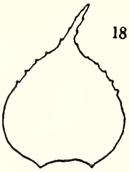
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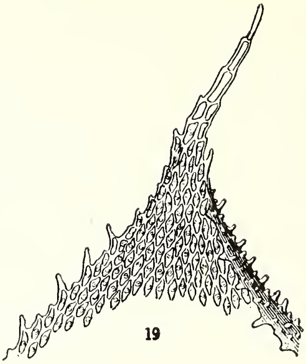
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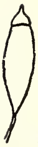
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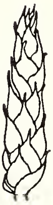
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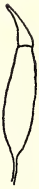
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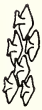
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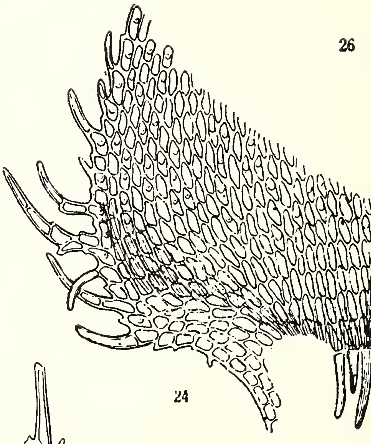
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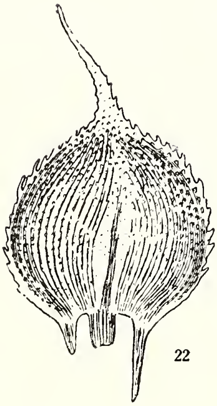
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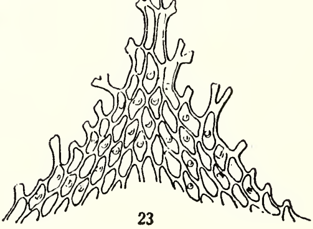
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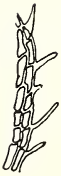
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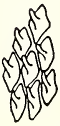
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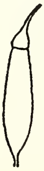
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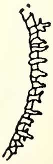
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LINDBERGIA

Plants medium in size, loosely tufted; stems elongate, thickly foliated, irregularly branched; gemmae of very short branchlets with minute papillose leaves frequently present; paraphyllia few to none; leaves imbricate when dry, spreading to squarrose when moist, concave, ovate to ovate-lanceolate, gradually broadly acuminate to rather abruptly and slenderly acuminate; apices often colorless; margins plane, entire, occasionally slightly irregular above; costa extending to middle of leaf or a little beyond; median cells rounded-oval to rhombic-fusiform; apical cell elongated; all cells except apical papillose with a large central papilla on each surface; capsule ovoid-cylindric, erect, symmetric; peristome double, outer of 16 lanceolate, obtuse, papillose teeth, deeply inserted, inner of a narrow membrane; operculum conic, obtuse.

L. brachyptera (Mitt.) Kindb. var. *Austinii* (Sull.) Grout. (Figs. 13-16.) Boone, Brown, Cass, Clinton, Daviess, Harrison, Hendricks, Jackson, Jasper, Jefferson, Jennings, Putnam, Scott, Steuben, Tipton, Wabash, and Wayne counties.

Subfamily THELIEAE

Plants small; branches julaceous; paraphyllia present in *Thelia* and absent in *Myurella;* leaves ovate to suborbicular, concave and somewhat spoon-shaped, costa single, short to almost absent, occasionally forked; cells of leaves papillose with large single or forked papillae or nearly smooth; capsules erect, symmetric; peristome perfect, with inner peristome imperfect to perfect.

Key to the genera of Thelieae

Costa single, reaching middle of leaf, or short, or forking; paraphyllia present; segments of inner peristome rudimentary to lacking. . *Thelia*

Costa short or lacking; paraphyllia absent; segments of inner peristome well developed, with cilia. . . . . *Myurella*

MYURELLA

Plants slender, small, growing in tufts or mats, light to glaucous green; stems irregularly branched; branches julaceous, often subfasciculate; small-leaved stolons present; paraphyllia absent; in *M. Careyana* leaves broadly round-ovate to suborbicular, abruptly apiculate to slenderly acuminate; margins spinose-dentate from base to apex; costa short to lacking; median leaf cells rounded-rhombic, pellucid, each with a very large dorsal papilla over the lumen; basal and apical cells elongated and nearly smooth; peristome perfect, segments of inner peristome about length of teeth, cilia two, shorter than the teeth; operculum conic.

M. Careyana Sull. (Figs. 17-20) Parke and Putnam counties.

THELIA

Plants small, growing in tufts or thin mats; stems regularly pinnate or nearly so; branches short, erect to ascending, julaceous, ends obtuse, light to glaucous-green; paraphyllia present; leaves closely imbricate when dry or moist, very concave, broadly rounded-ovate, abruptly subulate-acuminate; margins usually ciliate-serrulate, ciliate to laciniate below; costa single and extending to middle of leaf, or short, or forked; median leaf cells rhombic to fusiform, each with large, dorsal, single or forked papilla; peristome whitish, double, outer of 16 slender teeth and inner of a basal membrane with segments rudimentary or lacking; operculum conic, rostrate.

Key to species of Thelia

1. Papillae of dorsal cells of leaves branched, 2-4 points; leaf margins sometimes ciliate ....2.
    2. Plants growing on bark of trees; papillae usually 2-3 pointed; leaf margins with long cilia.............................*T. asprella*
    2. Plants growing commonly on sand or rock; papillae usually 3-4 pointed; leaf margins of many leaves indistinctly ciliate.......... ....*T. Lescurii*
1. Papillae of dorsal cells of leaves not branched, curved toward leaf apex; leaf margins spinulose-dentate above and fimbriate-ciliate below.... .... *T. hirtella*

T. asprella Sull. (Figs. 21-26.) Kosciusko, Lake, Noble, Putnam, and Steuben counties.

T. hirtella (Hedw.) Sull. (Figs. 27-29.) Brown, Jefferson, Jennings, Monroe, Owen, Porter, Putnam, Spencer, and Warren counties.

T. Lescurii Sull. (Fig. 30.) Floyd, Lake, and Porter counties.

Explanation of Plates A and B

Figs. 1-30, enlarged, unless otherwise indicated. Figs. 1-8, 10-15, 17-18, 20-21, and 25-30, Conard, How to know the Mosses, by permission; 9, 16, and 19, Grout, Moss Flora of North America north of Mexico 3: pls. 51 and 57, with permission; 22-24, Grout, Mosses with Hand-lens and Microscope, pl. 60, with permission. Figs. 1-3. *Anomodon attenuatus* (Conard, fig. 127). Fig. 1. Portion of foliated and attenuate stem. Fig. 2. Leaf. Fig. 3. Leaf apex. Figs. 4-5. *A. minor* (Conard, fig. 126). Fig. 4. Portion of foliated stem. Fig. 5. Leaf. Figs. 6-8. *A. rostratus* (Conard, fig. 125). Fig. 6. Portion of foliated stem. Fig. 7. Leaf. Fig. 8. Leaf apex. Fig. 9. *Haplohymenium triste* (Grout, M.N.A.M. 3: pl. 57). Branch, X 20. Fig. 10. *Leskea gracilescens* (Conard, fig. 129). Stem leaf. Fig. 11. *L. obscura* (Conard, fig. 129). Stem leaf. Fig. 12. *L. polycarpa* (Conard, fig. 129). Stem leaf. Figs. 13-16. *Lindbergia brachyptera Austinii* (Figs. 13-15, Conard, fig. 123; fig. 16, Grout, M.N.A.M. 3: pl. 51). Fig. 13. Portion of stem showing position of leaves when moist. Fig. 14. Leaf. Fig. 15. Leaf apex. Fig. 16. Papillose cells of portion of leaf base.

Figs. 17-20. *Myurella Carcyana* (Figs. 17, 18, 20, Conard, fig. 118; fig. 19, Grout, M.N.A.M. 3: pl. 51). Fig. 17. Portion of stem showing position of closely imbricated leaves. Fig. 18. Leaf. Fig. 19. Leaf apex showing cells and papillae. Fig. 20. Capsule. Figs. 21-26. *Thelia asprella* (Figs. 21, 25, 26, Conard, fig. 120; figs. 22-24, Grout, M.H.M. pl. 60). Fig. 21. Foliated branch. Fig. 22. Leaf. Fig. 23. Leaf apex. Fig. 24. Portion of leaf base. Fig. 25. Papillae Fig. 26. Capsule. Figs. 27-29. *T. hirtella* (Conard, fig. 121). Fig. 27. Margin of leaf. Fig. 28. Papillae. Fig. 29. Capsule. Fig. 30. *T. Lescurii* (Conard, fig. 120). Margin of leaf.

Oak Forests in the Laughery Creek Valley, Indiana*

J. E. Potzger, Butler University

Leland Chandler, Purdue University

The dissected wide valley of Laughery Creek offers a wide range of habitats with resultant major or minor changes in forest composition, ranging from mesic mixed hardwoods (beech, sugar maple, ash) on well-drained uplands or gentle slopes, to variants of oak-hickory type on steep slopes. One of these variants has been described in detail by Reynolds and Potzger (4), characterized by great abundance of *Quercus muhlenbergii*, a species which customarily has only small representation. In 1950 Potzger and Chandler (2) reported on ten stands of beech forests in this valley and a study of oak stands in the same region seemed essential for a concept of forest characteristics of the region in general.

It was a rather optimistic plan when the venture was made to study oak stands which had experienced little disturbance by man. From the highway many oak forests looked promising but upon closer observation were found poor for sociological studies to depict forest primeval conditions. Oak has been a valuable timber crop which has felt the pressure of lumbermen upon farmers for many years. Even though oak occupies the least favorable habitat sites, agriculturally speaking, the value of the timber made cutting a common occurrence. Only four suitable stands were found. Distribution of the stands is shown in figure 1.

Methods

Each stand was studied on basis of 20 ten-meter-square quadrats. The quadrats were delimited by stout cord, and all stems one inch or over were measured with wooden calipers. All young stems below one inch DBH. and at least three feet in height were tabulated. Such procedure gave information on abundance, diameter classes, reproduction, and per cent F. I.

Results

Tables 1 to 4 show results in summary form. The oak forests in Laughery Creek valley are not typical of the xeric oak type as one finds on south-facing slopes in unglaciated Indiana, as described in great detail by Potzger and Friesner (3). There are really four variants characterized by different combinations of oak species, viz. *Quercus muhlenbergii-Q. rubra* (Table IV), *Q. alba-Q. muhlenbergii-Q. rubra* (Table III), *Q. alba-Q. rubra* (Table I), *Q. alba-Q. velutina* (Table II).

One hesitates to classify the forest complex as typical oak-hickory, even though Carya has a high representation, because of very important representation of the climax forest species, such as Fagus, *Acer saccharum* and species of Fraxinus. The climax forest species are especially abundant in the small stem sizes, but may also play an important part in crown control (Tables I, II, III).

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* This is publication 256 of the Botany Laboratory of Butler University, and paper 4 of the Purdue Conservation Camp faculty.

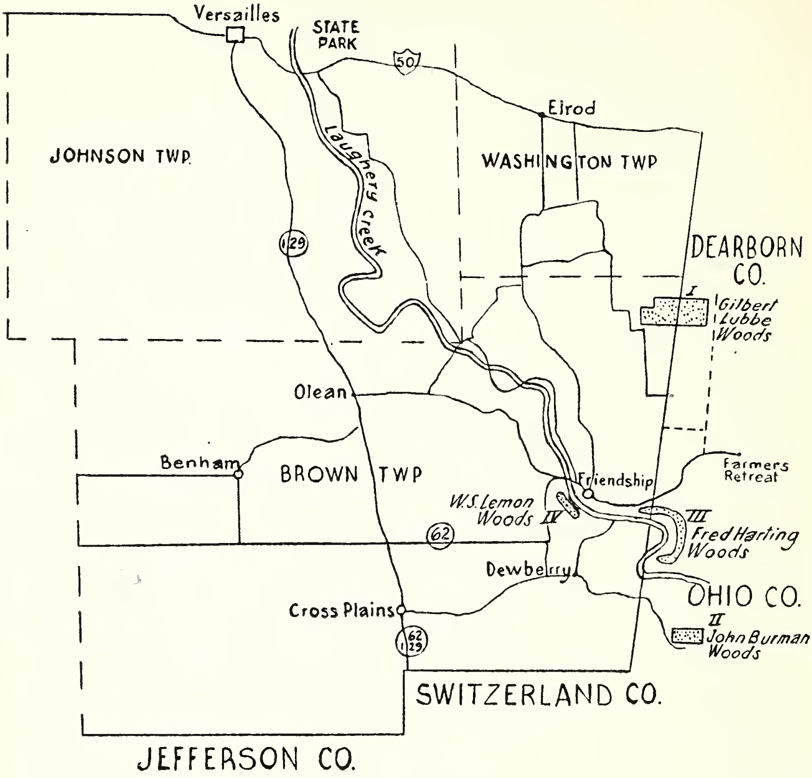

Figure 1. Sketch map showing location of the four stands of oak with reference to townships and highways.

The least typical oak forest is the Lubbe woods (Table I). The habitat is a moderately dissected upland. The crown cover is really more beech-maple-ash than oak-hickory, but the oaks are mostly magnificent giant trees, up to 54 inches DBH. The eye is held spellbound by the immense trunks of white oak so that the true sociology of the forest association and prominent crown control by beech, sugar maple, and ash go unobserved until a quadrat study is made. Fagus, *Acer saccharum*, and *Fraxinus americana* have each a higher frequency index than *Quercus alba*. The almost total lack of reproduction by oaks suggests decadent status of oak in the crown cover (Table I).

Discussion

In an area like Indiana, where the most favorable habitat sites are convered by a mixed hardwoods of mesic species, especially beech, sugar maple and ash, one can expect a mosaic of forest cover types which represent ranges in soil moisture between beech-maple-ash mesic condition on the one hand and the oak-hickory xeric condition on the other, as Potzger (1) has described for the Versailles Park area. The Laughery

TABLE I. Tabulation of woody species in twenty 10-meter-square quadrats in the Lubbe woods. Diameter classes in inches.

Species	Below 1 in.	1-2	3-5	6.9	10-15	16-20	Above 20	Total 1 in. or above	Per cent F. I.
Acer rubrum	20	9	1	2	1			13	60
A. saccharum	91	42	15	4	1			62	95
Carya cordiformis							1	1	5
C. glabra	17	8	5	1	1			15	60
C. ovata	8	2	1	1				4	35
Celtis occidentalis	1								5
Cornus florida	56	31	16					47	75
Fagus grandifolia	54	35	9	4	7	2	1	58	100
Fraxinus americana	30	4	2	2				8	85
F. pennsylvanica	22	2						2	40
F. quadrangulata	2	1						1	15
Liriodendron tulipifera	1	2						2	15
Morus rubra	13	1						1	30
Nyssa sylvatica	17	7	1		1	1		10	20
Ostrya virginiana	63	5	6					11	65
Prunus serotina	18							—	20
Quercus alba	3						11	11	55
Q. rubra					2		3	5	25
Q. velutina			1					1	5
Sassafras albidum	3	2						2	15
Ulmus americana	10							—	15
U. fulva	5	4	1	1				6	25
Amelanchier canadensis	2	1						3	15
Aralia spinosa	3							3	5
Celastrus scandens	4							4	10
Dirca palustris	16							16	20
Euonymus atropurpureus	2							2	5
Lindera benzoin	3							3	10
Smilax glauca	40							40	45
S. rotundifolia	5							5	5
Viburnum acerifolium	100							100	60
V. prunifolium	1							1	5
Vitis spp.	11							11	30

TABLE II. Tabulation of woody species in twenty 10-meter-square quadrats in the John Burman woods. Diameter classes in inches.

Species	Below 1 in.	1-2	3-5	6.9	10-15	16-20	Above 20	Total 1 in. or over	Per cent F. I.
Acer saccharum	389	215	25	1			2	243	100
Amelanchier canadensis	3	2						2	25
Carya cordiformis				1	4			5	15
C. glabra	9	6	1	3	5			15	45
C. ovata	19	5	2	3	7	2		19	75
Celtis occidentalis		1						1	5
Cercis canadensis	4	3						3	20
Cornus asperifolia	1	1						1	5
C. florida	16	32	4					36	60
Crataegus sp.	1								5
Fagus grandifolia	4	6						6	5
Fraxinus americana	36	21	3					24	80
F. pennsylvanica	2							—	5
Juglans nigra				2				2	10
Juniperus virginiana	1							—	5
Morus rubra	8	2	1					3	45
Nyssa sylvatica	3								5
Ostrya virginiana	56	28	2					30	45
Prunus serotina	3		1					1	20
Quercus alba	18	8		3		4	11	26	75
Q. velutina	4	2				6	4	12	45
Sassafras albidum	1							—	5
Ulmus americana		1	1	1				3	15
U. rubra	24	12	1					13	50
Celastrus scandens	7								15
Euonymus atropurpureus	6								5
Rhus glabra	1								5
Smilax glauca	1								5
Viburnum prunifolium	6	1						1	20
Vitis sp.	1							—	5

TABLE III. Tabulation of woody species in twenty 10-meter-square quadrats in the Fred Harting woods. Diameter classes in inches.

Species	Below 1 in.	1-2	3-5	6.9	10-15	16-20	Above 20	Total 1 in. or over	Per cent F. I.
Acer saccharum	339	112	37	3		4	1	157	100
Aesculus glabra	9	4	2	2				8	40
Carpinus caroliniana	5							—	10
Carya cordiformis	2			2	2			4	30
C. glabra		2	2	2		3		7	30
C. ovata	11	3	8	5	1	2	1	20	70
Celtis occidentalis	2	1	1					2	15
Cercis canadensis	25	9						9	55
Cornus florida	3	4	2					6	25
Fagus grandifolia	1	4	3					7	20
Fraxinus americana	60	8	4	3	1		1	17	80
F. quadrangulata	59	4						4	85
Juglans nigra				3				3	10
Morus rubra	30	2						2	70
Ostrya virginiana	21	24	6					30	60
Prunus serotina	1	1						1	10
Quercus alba			14	11	7	5	1	38	60
Q. muhlenbergii	4		3	5	6	3	2	19	45
Q. rubra	3		2	4	3	2	1	12	50
Q. velutina					2			2	10
Sassafras albidum	3							—	5
Ulmus rubra	25	13						13	85
Celastrus scandens	8							—	15
Euonymus atropurpureus	1							—	5
Parthenocissus quinquefolia	5							—	20
Ribes sp.	14							—	25
Smilax glauca	5							—	15
Viburnum prunifolium	3							—	10
Vitis sp.	2							—	10

TABLE IV. Tabulation of woody species in twenty 10-meter-square quadrats in the Lemon woods. Diameter classes in inches.

Species	Below 1 in.	1-2	3-5	6.9	10-15	16-20	Above 20	Total 1 in. or over	Per cent F. I.
Acer saccharum	110	63	42	12	4	2		77	100
Aesculus glabra	16	7	5					12	55
Carpinus caroliniana	3	2						2	10
Carya cordiformis	1	1	5	11	11	1		29	60
C. glabra	1	2						2	15
C. ovata		1	6	7				14	35
Celtis occidentalis	2	2	1	2	1			6	15
Cercis canadensis	19	4	1					5	40
Cornus asperifolia	10							—	10
C. florida	1							—	5
Crataegus sp.	1							—	5
Fraxinus americana	33	8	8	5	2	1		24	90
F. quadrangulata	4		1					1	15
Juglans nigra				3	2			5	20
Morus rubra	3							—	15
Ostrya virginiana	14	6	15					21	60
Quercus muhlenbergii			1	3	1			5	25
Q. rubra	1			3	10	2	1	16	45
Q. velutina	3	1				1		2	15
Tilia americana	11	8	3	6	4			21	40
Ulmus americana	1	2	2	2				6	30
Ulmus rubra		4		3	2			9	35
Asimina triloba	5							—	5
Celastrus scandens	14							—	5
Dirca palustris	9							—	20
Euonymus atropurpureus	1							—	5
Parthenocissus quinquefolia	29	1						1	60
Ribes sp.	7							—	20
Smilax glauca	4							—	15
Viburnum prunifolium	17							—	25
Vitis sp.	4	2	1					3	15
Xanthoxylum americanum	13	1						1	10

Creek valley is perhaps unique in the variants of oak forests (Tables I-IV). This is evidently determined by the mosaic of numerous microclimatic habitats on the slopes of deep-set Laughery Creek and its tributaries. The extreme competition which the climax mixed hardwoods places upon oak-hickory is well shown by the present study. Only in the John Burman woods (Table II) does reproduction by oaks seem adequate for continuation of prominent crown control by species of oak.

A unique feature in the Laughery Creek valley is as shown by Potzger and Reynolds (4) and Potzger (1) as well as by Tables II and IV of this study, the prominent role played by *Quercus muhlenbergii.* If one compares the composition of oak forests in the Laughery Creek valley with those of xeric south-facing slopes of Brown, Monroe and other Indiana counties with dissected topography it becomes quite evident that the Ripley county habitats must be less xeric and so have a more transitional oak-hickory forest cover.

Summary and Conclusions

1. The study presents qualitative and quantitative data on four oak-hickory stands in the Laughery Creek valley.
2. The oak-hickory forest appears to be transitional in nature, since dominants of the climatic climax (Fagus, Fraxinus, and *Acer saccharum)* usually assume a prominent place in crown control.
3. A unique feature is the unusual importance of *Quercus muhlenbergii* in the oak forests of the region.
4. Oak-hickory forest is apparently limited to steep slopes.
5. The Lubbe woods has without doubt some of the most magnificent large trees of *Quercus alba* in Indiana.

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Notes on Indiana Liverworts—V[1]

KENNETH A. WAGNER, Florida State University

A grant from the Indiana Academy of Science through the American Association for the Advancement of Science enabled the writer to collect in seven state parks in Indiana during the past summer and to visit the University of Illinois to study the Indiana collections made by E. J. Hill. The new distribution records from this trip and from collections sent to the writer by Dr. Winona H. Welch are reported here. Except for the E. J. Hill collections, all specimens listed here are in the DePauw University herbarium.

Blepharostoma trichophyllum (L.) Dum. Fountain Co.: on sandstone, Portland Arch, Aug. 17, 1952, Wagner 3052 in part. This minute species has been reported in Indiana from two other counties, Montgomery and Putnam. In all cases, it was found growing on wet sandstone.

Cephalozia connivens (Dicks.) Lindb. Porter Co.: Dunes State Park, July 16, 1912, E. J. Hill 27.1912.

C. media Lindb. Fountain Co.: on sandstone Portland Arch, Aug. 17, 1952, Wagner 3052 in part; Porter Co.: Dunes State Park, June 22, 1907, E. J. Hill 24.1907 in part.

Odontoschisma denudatum (Mart.) Dum. Porter Co.: Dunes State Park, June 26, 1907, E. J. Hill 24.1907 in part. First report for Indiana; the collection contains typical plants with denuded stem tips and gemmae.

O. prostratum (Swarz.) Trevis was reported by the writer for three counties in Indiana (Wagner 2) on the basis of fragments found among other bryophytes. A further study of *O. prostratum*, essentially a coastal plain species which reaches its best development here in Florida where it grows on rotten wood, places the Indiana records somewhat in doubt. During the past summer considerable quantity of an *Odontoschisma* with distinct ventral leafless flagelliform branches was collected on sandstone at Turkey Run (Wagner 3051). It agrees with the above species in all vegetative characters except its smaller leaf size. The cell size, however, is within the range of typical *O. prostratum*. These collections are tentatively referred to *O. protratum*, although the discovery of fertile material may show that it is a distinct taxon, probably a variety.

Lophocolea cuspidata (Nees) Limpr. Fountain Co.: on sandstone, Portland Arch, Aug. 17, 1952, Wagner 3052 in part.

Chiloscyphus pallescens (Ehrh.) Dum. Washington Co.: on damp limestone with *Conocephalum*, W. D. Gray 1131.

C. polyanthus (L.) Corda. Jefferson Co.: Clifty Falls State Park, with *Cololejeunea biddlecomiae*, Sept. 12, 1952, Wagner 3043. Previously reported in Indiana from Martin and Wells counties.

Harpanthus scutatus (Web. & Mohr) Spruce. Fountain Co.: on sandstone, Portland Arch, Aug. 17, 1952, Wagner 3053 in part. This species is recognized by the large underleaves which are long-lingulate triangular and not bilobed. The previous Indiana record was based on fragmentary material from Putnam County. The excellent material found at Portland Arch reduces doubts which the writer held concerning the Putnam County record.

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[1] Contribution No. 56, Botanical Laboratory, Florida State University.

Geocalyx graveolens (Schrad.) Nees. Lake Co.: Oct. 27, 1898, E. J. Hill 367.1898.

Plectocolea crenuliformis (Aust.) Mitten. Lake Co.: Liverpool, Oct. 27, 1898, E. J. Hill 370.1898 (as *Nardia crenulata).* This is the first report of this species in Indiana north of Fountain County.

Diplophyllum albicans (L.) Dum. was reported for Indiana (Frye and Clark) based on a collection by Drexler no. 1424 at Turkey Run State Park. During the writer's stay at Turkey Run, an intensive search was made for this species, but all field checks and all determinations made to date have yielded only the common *D. apiculatum. Diplophyllum albicans,* as the writer understands it, is a northern alpine species. Its natural occurrence anywhere in Indiana, even as a relic at Turkey Run, would be surprising. It should be readily identified by the whitish costa-like row of cells on upper and lower lobes of the leaves.

Porella pinnata L. Posey Co.: on birch, Hovey Lake, Aug. 5, 1952, Wagner 3048.

P. platyphylla (L.) Lindb. Warren Co.: on sycamore, Hanging Rock Camp, May 27, 1951, W. H. Welch 11720; Decatur Co.: on elm, W. D. Gray 1052; Clark Co.: on limestone, Nine Penny Creek, W. D. Gray 1023.

Frullania eboracensis Gottsche. Clark Co.: on base of beech tree, W. D. Gray 1084; Fountain Co.: on sugar maple, Portland Arch, Aug. 17, 1952, Wagner 3050.

Frullania riparia Hampe. Jefferson Co.: on limestone, Clifty Falls State Park, Sept. 12, 1952, Wagner 3040.

Frullania squarrosa (R. Bl. & Nees) Dum. Posey Co.: on American ash, five miles southeast of New Harmony, on U. S. 460, Aug. 5, 1952, Wagner 3046.

Cololejeunea biddlecomiae (Aust.) Evans. Fountain Co.: on sandstone, Portland Arch, Aug. 17, 1952, Wagner 3049. Although reported from eleven counties in Indiana, this species has not been found within the state north of Fountain, Montgomery, Madison and Randolph counties. It does occur as far north of Indiana as Ontario, although the genus is primarily a tropical one.

Fossombronia foveolata Lindb. Putnam Co.: East Fern on clay soil along road, shade, June 10, 1947, W. H. Welch 11440.

Pellia epiphylla (L.) Corda. Lake Co.: April 28, 1904, E. J. Hill 5.1904; Fountain Co.: on sandstone, Portland Arch, Aug. 17, 1952, Wagner 3055.

Metzgeria conjugata Lindb. This species is known in Indiana only from Turkey Run State Park in Parke County. According to Frye and Clark (1), it has been reported from such widely scattered places as Maine, Florida, California, Alaska, New Zealand, South America, Africa and Asia. This indicates that features of the microclimate may be responsible for its limited distribution in Indiana. The writer has searched for this species in other parts of the state since starting work on the Indiana liverworts in 1945. To date, no additional sites have been found, although a thorough check was made last summer at Fern near Greencastle, a most logical place for the species. It was found at Turkey Run in varying abundance in all ravines north of Sugar Creek.

The sites at Turkey Run which produced the best growth of *Metzgeria* seemed to involve at least two factors, light and humidity. The best colonies were at the bottoms of deep ravines but nevertheless received direct sunlight for some portion of the day. Good growth occurred where the ravines were relatively wide and never in the very narrow portions.

After examining seven ravines at Fern, it seems probable the *Metzgeria conjugata* does not grow there because the ravines are not deep enough to provide the required humidity. Several places were examined which were comparable to the sites at Turkey Run in exposure to light, in the presence of associated species and in composition of the substrate but the *Metzgeria* could not be found.

Inasmuch as this species is found from Alaska to Florida, the gross aspects of the climate would seem not to be important in its Indiana distribution.

Riccardia pinguis (L.) S. F. Gray. Lake Co.: Liverpool, Aug. 18, 1902, E. J. Hill 163.1902.

Conocephalum conicum (L.) Dum. Washington Co.: damp limestone, W. D. Gray 1131.

Preissia quadrata (Scop.) Nees. Montgomery Co.: on soil over sandstone, The Shades State Park, Aug. 14, 1952, Wagner 3047.

Reboulia hemisphaerica (L.) Raddi. Fountain Co.: moist sandstone, Portland Arch, Oct. 17, 1942, G. N. Jones 15539.

Ricciocarpus natans (L.) Corda. Clark Co.: May 7, 1898, L. M. Umback.

Anthoceros laevis L. Lake Co.: near Gary, Sept. 23, 1898, E. J. Hill 270.1898.

Literature Cited

1. FRYE, T. C., and L. CLARK. 1937-1946. Hepaticae of North America. Univ. of Washington Pub. in Biology 6:1-733.
2. WAGNER, K. A. 1946. Additions to the Hepatic Flora of Indiana. Bryologist 49:125-126.

Effect of Aging on the Viability of Sporocarps of *Marsilea quadrifolia*[1]

WILLIAM W. BLOOM, Valparaiso University

The Marsileaceae is a small group of water ferns distinguishable from all other Leptosporangiatae but the Salviniaceae by their heterospory. In contrast to the Salviniaceae, the sporocarps of the Marsileaceae contain both microspores and megaspores. The morphology of the Marsileaceae is discussed rather fully by Bower (1), Eames (2), and Smith (3) and in a number of individual reports dating back to the late nineteenth century.

One of the more unusual characteristics of this group of ferns is their mode of sexual reproduction. Both megaspores and microspores occur in each sorus and are produced in a special organ, the sporocarp. These closed, more or less globular structures are developed from leaves or leaf segments. When mature they possess a hard, resistent outer coat which serves to protect the spores against mechanical injury, desiccation and some unfavorable substances to which they might be exposed.

There is considerable interest in the sporocarps of the Marsileaceae because of their apparent resistance to the effect of aging upon the viability of the spores. Eames (2) reports that sporocarps taken from herbarium sheets 50 years old have "germinated" and Smith (3) reports that spores remain viable for 20 or 30 years.

The successful sexual reproduction of the Marsileaceae depends on several successive steps. When placed in water, especially if the hard outer coat is ground or filed, water is imbibed, resulting in expansion and rupturing of the sporocarp. In some species the sori contained in the sporocarp are pulled out into the water by means of a greatly expanded gelatinous ring but in other species the individual spores are eventually freed from the sporocarp or may remain within the sporocarp walls. This phenomenon is commonly referred to as "germination" although it is purely physical and may occur even though none of the spores contained in the sporocarp are viable. It is evident that some of the reports on germination represent an observation of this first stage only.

Following germination the spores develop into gametophytes rapidly, the rate being partially controlled by temperature, and varies considerably for different species. Generally 24 to 48 hours are sufficient for the complete initiation and maturation of the gametophytes. This development can be readily detected under low magnifications of the microscope. In mature microgametophytes the motile sperms are readily detected and the ruptured microspore walls are in evidence. The megagametophyte can be recognized as the cushion of green cells at the site of what was a small

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[1] This work was supported in part by a grant from the Dr. Wallace C. and Clara A. Abbott Memorial Fund of the University of Chicago.

TABLE I. Sporocarp germination, gametophyte and functional embryo sporophyte formation.

No. of sporocarp	Germination	Microgametophyte development	Megagametophyte development	Functional embryo formation
1	+	+	+	+
2	+	+	+	+
3	+	0	0	0
4	+	+	+	+
5	+	+	+	+
6	+	0	0	0
7	+	0	0	0
8	+	+	+	+
9	+	+	+	+
10	+	+	+	+

TABLE II. Viability of megaspores as shown by the development of embryo sporophytes.

No. of sporocarp	No. of viable megaspores	No. of non-viable megaspores	Percentage of viability
1	105	0	100.00
2	98	3	97.03
3	0	87	0.00
4	75	0	100.00
5	93	1	98.94
6	0	91	0.00
7	0	69	0.00
8	57	1	98.27
9	73	3	96.05
10	78	2	97.50

protuberance at the anterior pole of the megaspore. The neck-cells of the single archegonium are usually discernable.

A collection of sporocarps of *Marsilea quadrifolia L.* made by the late Miss Ethel Thomas of the Department of Botany of Eastern Illinois State College at Charleston, Illinois, was furnished the writer by Dr. Paul D. Voth of the Department of Botany of The University of Chicago. These sporocarps had been collected in 1922 and preserved dry in a small cardboard box. For at least a part of the 30 years since they were collected they were stored in the humid basement of the Hull Botanical Laboratories at The University of Chicago. Conditions under which they were collected are unknown and the percentage of germination or fertility at the time of collection was not determined.

In order to determine whether the spores in the sporocarps were still viable and to what extent they might have deteriorated in storage, 10 selected sporocarps were rubbed on fine emery paper to hasten germination and placed in individual glass vials, each 2 cm. by 8 cm. and containing 22 ml. of tap water. Observations were made daily and the results recorded. The results are shown in Tables I and II. The opening of the sporocarps with the development of the gelatinous ring was taken as a criterion of germination. The presence of opened microspores and of motile sperms was taken as evidence of viable microspores. The development of the megagametophyte and subsequent formation of an embryo was taken as evidence of a viable megaspore.

Discussion

Several facts are noted from an examination of the results shown in Tables I and II. In numbers 3, 6 and 7 all the megaspores and apparently the microspores are 100% non-viable. It is impossible to attribute this to conditions peculiar to them at the time of harvesting or to an effect of aging. Judging from the completeness of non-viability, the former would seem to be most likely, especially when compared with the high percentages of viability in the other sporocarps. The behavior and appearance of the megaspores also suggests this. In no. 3 most of the megaspores remained within the sori and had a deflated appearance. The megaspores in no. 7 had a peculiar structure extending out from the anterior portion of the megaspore and the spores hung down rather than assuming a horizontal position. The megaspores in no. 7 remained within the sori.

Of the seven sporocarps showing viability, 579 megaspores were viable and developed functional gametophytes resulting in the formation of embryo sporophytes as compared to 10 non-viable megaspores. For these seven sporocarps a decline in fertility at most was 1.7% in 30 years. It will be noted that this is a much smaller decline than is shown by the seeds of most spermatophytes and probably exceeds that of even the more resistant bacterial endospores.

It is interesting to note the wide variation in the number of megaspores that developed in various sporocarps. Number 1 had a total of 105 megaspores while number 8 had only 58.

Summary

1. Germination of sporocarps of *Marsilea quadrifolia L.* is a physical phenomenon and is independent of viability of the spores.
2. A total of 589 megaspores of *Marsilea quadrifolia L.* 30 years old showed a loss in viability of less than 2%.

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1. BOWER, F. O. 1926. The Ferns, Vol. II. Cambridge University Press. London.
2. EAMES, A. J. 1926. Morphology of vascular plants, lower groups. McGraw-Hill Book Co., Inc. New York.
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Higher Fungi of Marion County, Indiana

JOHN O. COTTINGHAM, Indianapolis

Agaricaceae
- *Hypholoma cutifractum* Pk.
- *Lactarius volemus* Fr.
- *Lentinus lepidius* Fr.
- *Marasmius cohaerens* (Fr.) Bres.

Polyporaceae
- *Polyporus elegans* (Fr.) Bull.
- *Trametes Peckii* Kalchb.

Phallaceae
- *Mutinus caninus* Fr.

The above list makes a total of 372 species that have been thus far reported.

CHEMISTRY

Chairman: E. L. HAENISCH, Wabash College

J. H. BILLMAN, Indiana University, was elected chairman for 1953

ABSTRACTS

The dissociation constant of dichloro-argentate ion. MARTIN ALLEN, Butler University.—A method proposed by Reynolds and Argersinger (1) for the determination of the constitution and dissociation constant of a complex ion has been applied to the dichloro-argentate ion. Equations, modifications of those derived by Reynolds and Argersinger but taking into account incomplete ionization of silver chloride, were applied to the data of Jonte and Martin (2) who studied the solubility of silver chloride in aqueous sodium chloride solutions using a radioassay technique. Results of the calculations are in good agreement with those of previous investigators: the number of chlorides coordinated to the silver is two and the dissociation constant of the complex ion is 7.5×10^{-6}.

1. REYNOLDS, C. A., and W. J. ARGERSINGER, JR. 1952. Constitution and stability of complex ions from solubility minima. J. Phys. Chem. 56:417-420.
2. JONTE, J. H., and D. S. MARTIN, JR. 1952. The solubility of silver chloride and the formation of complexes in chloride solution. J. Amer. Chem. Soc. 74:2052-2054.

The estimation of azeotropic composition. KEITH M. SEYMOUR, Butler University.—Early attempts at correlation of the composition of binary azeotropes with the boiling points of the components by Lecat were not useful. Correlations of azeotropic properties with the properties of the components have been published in recent years but none involving composition and component boiling points has been observed.

This paper presents a correlation which may be used for the estimation of the composition of azeotropes formed between several types of compounds. Data on a series of azeotropes between normal hydrocarbons and normal primary alcohols are reported. The composition of certain azeotropes whose properties seemed anonolous have been redetermined.

A realistic approach to the training of chemists in safety. J. S. PEAKE and C. S. ROHRER, Indiana University.—Our increasingly complex chemical industry needs mature and responsible personnel. Such competence is essential for dealing with industry's increasingly dangerous operations.

It is reasonable that professional chemists be trained from the first to be orderly, logical and safe in their planning and work. The best time for indoctrinating professional chemists is during their professional training. Habits acquired early are habits which stick. Every lecture or laboratory course offers a golden opportunity for such indoctrination. The safe way is always the best way and can be learned from the start.

The college and university chemistry departments need to awaken to their neglected responsibility to industry and to society by official adoption of programs of safety. Students at Indiana University have shown a willingness to cooperate with the safety program, if given a logical explanation and a cooperative enforcement by the faculty. Supplemental aids include suitable safety manuals, safety films and posters. Student-faculty safety committees, regular building inspections and the study of accident statistics taken within the department stimulate interest and help to eliminate hazardous practices and situations.

The chemistry departments adopting effective safety programs will gain favorable recognition from industry for producing graduates with a mature, professional attitude.

Quantitative determination of individual volatile organic acids by chromatography. R. M. BROOKER, Indiana Central College, H. A. NASH and A. R. SMASHEY, Pitman-Moore Co.—The separation of fatty acids by means of a chromatographic column of moist silicic acid and a chloroform-*n*-butyl alcohol mixture as the moving phase has been described by Marvel and Rands [J. Am. Chem. Soc., 72:2642 (1950)]. This method could be used for the quantitative determination of the individual volatile organic acids from the hydrolysis of esters if the free acids could be placed on the silicic acid column quantitatively. To accomplish this, we used the following procedure. The slightly alkaline hydrolysis mixture or slightly alkaline steam distillate containing the volatile acids was concentrated *in vacuo* and finally lyophilized. The solid sodium salts of the acids were dissolved in a small amount of water, the solution stirred with silicic acid and mixed with chloroform freshly saturated with hydrogen chloride. This was slurried onto the silicic acid column with chloroform and developed according to the procedure of Marvel and Rands.

In applying the procedure of Marvel and Rands to the separation of organic acids from the hydrolysis of alkaloids from *Veratrum Album*, it was found that the chloroform-*n*-butyl alcohol mixture failed to separate acetic acid and 2-hydroxy-2-methylbutryic acid. The use of technical *n*-butyl chloride (containing 5% *n*-butyl alcohol) gave excellent separation.

A Schematic Chart for the Qualitative Analysis of Cations. JOHN M. CHRISTENS, Indiana University (Contrib. No. 553 from the Chemistry Department).—A streamlined "flow sheet"-type chart was designed as a compromise between the separate group outlines usually found in textbooks and the complete and complicated charts available commercially. The chart follows the analysis scheme of J. H. Reedy (Elementary and Theoretical Qualitative Analysis, McGraw-Hill 1938, N. Y.). Graphic representation was emphasized as much as possible: funnels indicate separations in solutions and precipitates, solid compounds are underlined and their color given, ionic formula of cations in solution indicated. Alternate methods are kept to a minimum (only the NH_4OH-H_2S method is given for group III) and unusual tests (such as for oxalates and phosphates) are referred to the textbook. The reagents added are indicated but their volumes were omitted (together with the treatment of a solid unknown) to streamline the chart.

The students were asked, in the laboratory, to keep track of their successive operations on the chart and were expected to be able to justify the use of each reagent. The chart was found useful in keeping down laboratory mistakes and in studying the analysis scheme. A minimum of descriptive information concerning each cation (properties, complex ions, flame tests, etc.) were given in a column at the right of the chart.

Blueprinted copies of the chart (18"x24") are available upon request.

A Mine Water Problem

W. G. Kessel, Indiana State Teachers College

Any materials that change the nature of natural waters, whether they are from industry or not, offer many perplexing problems to those who may need to use these waters. Today the problem of waste water treatment falls heavily upon the shoulders of many industries. It is most difficult to find satisfactory, economic procedures to treat various wastes. It is desirable that when they are dumped into nearby streams, rivers, and lakes the water does not become too offensive in color, odor, etc.; does not kill aquatic life and is not too difficult for others to purify. As you are probably aware many states now have laws that make it mandatory to treat all waste discarded into public waters. Each industry therefore has particular problems, ones that are peculiar to their own operations. Consequently some have had success and others have spent time, money, and energy on problems of this nature and as yet have no satisfactory solutions.

Such an unsolved problem is the subject of this paper.

About two years ago the author first became aware of the phenomenal change in pH that occurs in "spoil banks" on exposure to air. In Vigo County, strip mining operations cover some 10,000 acres, about 5% of the total area. The problem of reforestation as required by Indiana law is a large one. In these stripping operations the overburden of rock and soil is removed from the coal seams and piled into what the trade calls "spoil banks." The composition of this overburden and the "high wall" in the pits includes considerable iron sulfides as pyrite and marcasite, which oxidize on exposure to the air. The soil then becomes very acid and drainage water and/or strip pit lakes often have a pH on the acid side. One such lake was found with a pH of 2.1. Of course, the planting of trees in these soils is useless but most of the acidity will eventually be leached out.

J. J. Berzelius early noted this acid condition of mine waste water. A more recent statement by Eskell Nordell, "In mines, the free sulfuric acid and metallic sulfates are formed by the oxidation of sulfur containing materials, notably pyrites. The commonest of these as marcasite or brassy iron pyrites, which yields sulfuric acid and ferrous sulfate on oxidation in the presence of moisture."

Early in the spring of 1952 a similar condition was confronted by a mining corporation in this area when they were threatened with a law suit because their acid waters were affecting a creek so much that stock would not use this water.

This is a shaft mine where a pump moves the waters from the underground chambers so the miners can operate. This water then runs into a nearby creek and then progresses toward the Wabash. The pump water is acid and as it flows through calcareous material the pH drops and considerable iron is precipitated on the bottom and is also carried on down stream.

TABLE I

Composition of Pump Water Color—usually very clear no H_2S apparent very little dissolved CO_2	
dissolved solids	3658 ppm
sulfate	408 ppm
iron	200 ppm
aluminum	155 ppm
SiO_2	6 ppm
calcium	327 ppm
magnesium	845 ppm
mineral acidity	?

TABLE II

March 6	3.5 pH	
13	4.0 pH	
26	3.5 pH	
April 26	4.1 pH	
30	5.1 pH	
May 13	4.9 pH	260 Fe ppm
21	5.2 pH	268 Fe ppm
27	5.0 pH	260 Fe ppm
June 4	5.1 pH	240 Fe ppm
18	5.5 pH	285 Fe ppm
July 19	5.3 pH	300 Fe ppm
Aug. & Sept.—no determinations		
Oct. 2	5.7 pH	240 Fe ppm
14	5.5 pH	

Table I shows the composition of this pump water. Table II shows the changing nature of the pump water.

It is apparent from Table II that the idea of installing a larger pump in order to move the water more rapidly was of some value. For the pH seems to be moving up since May 20. Also at this time a move was made to aerate the water as it came from the pump. This was accomplished by building a wood trough about twelve feet long, four feet wide, and two feet deep. The bottom was then slit into many sections with a saw thus allowing the water to spray through it. The trough was then placed about ten feet from the ground and the water from pump goes directly into it.

After this spray the water passes through a holding basin some twenty feet wide and two or three feet deep about a hundred yards long. Then over some small log dams and cascades into a creek and on to the Wabash. Before this aeration was installed there was no reddish iron precipitate in the basin or in the creek at this point. Now the bottom of the holding basin and the creek where the pump water enters is covered with the reddish iron.

The sulfur content however is still high, for the water changes in pH very noticeably as it passes on down stream as shown in Table III from the October sample.

TABLE III

sample	*pH*
No. 1 pump	5.7
No. 2 after spray	5.8
No. 3 creek	7.3
No. 4 pump water in creek	5.8
No. 5 approx. 1 mile	3.6
No. 6 approx. 2 miles	6.0
No. 7 approx. 4 miles	7.2

Some modifications of the aeration operations are now under way, the idea again being to completely oxidize the sulfur at the pump area. Then as the water contacts various limestone containing materials, the iron will be precipitated out and not carried on down the stream.

The idea of neutralizing the pump water as suggested by Eskel Nordell, page 78, "neutralization aerations, settling and filtrations," was tried. It is, as he suggests further on in this consideration, futile, "for they are so high in sulfates hardness and acid that they are practically beyond redemption." Figures indicate that neutralization with the conventional alkalis would cost approximately 5¢ per 100 gallons. This is of course prohibitive. Limestone scrap is also of little value for it soon coats with insoluble calcium sulfate and is worthless.

Neutralization is of little help in this situation unless the sulfur content has been completely oxidized. Samples of the pump water were put in contact with limestone for twenty-four hours and the acidity present was completely neutralized. But when this water was then allowed to stand in the air, not in contact with the limestone, the pH dropped back considerably. This sequence could be repeated again until all of the oxidation had been complete.

Several other ideas are now in progress of consideration that perhaps will help to solve this unique problem for the acid mine wastes.

Literature Cited

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2. NORDELL, ESKEL. 1951. Water Treatment for Industrial and Other Uses. p. 76.

Reinforcement of Natural Rubbers by Fillers[1]

JOHN M. CHRISTENS, Indiana University

The importance of fillers in the field of rubber compounding is well known. Fillers can be reinforcing (as carbon black in tires), they can be inert (as $CaCO_3$) and silica has been reported as elasticizing.

The process by which fillers modify the mechanical behavior of natural rubber is not thoroughly understood. Considerable progress has been made by the use of the electron microscope in the study of the size and shape of the particles of fillers and of the interaction between these particles and the rubber molecules.

Some factors have been determined: carbon black adsorbs the "sol" fraction of rubber preferentially (5), the size of the particles of filler must remain between rather narrow limits (9b) (25 to 35 $m\mu$ for carbon black) otherwise the contact is poor or the rubber is degraded by the heat generated by too small particles, a too acidic or too basic filler slows the vulcanization down considerably (6) which justifies the coating of basic fillers (such as calcium carbonate) with fatty acids and of acidic fillers (such as kaolin) with basic organic compounds. In either case, the organic "tail" is in contact with the rubber and the adsorption upon the filler is favored.

Testing Conditions

In final resort, the testing of the influence of the filler must be made by measuring the mechanical properties of the vulcanized mixtures. The testing itself can involve one or more of the following: tension testing (ultimate tensile strength, elongation at break and elastic moduli), tear resistance, abrasion, etc. We used "dumbell"-shaped samples with a straight-away part of dimensions 25 x 2 x 2 mm. as adopted by the French Rubber Institute (7). The other conditions (speed of testing, etc.) were as close as possible to the recommendations of the A.S.T.M. (7). The machine used was a modified textile machine equipped with specially designed jaws.

In testing the fillers, the following proportions were respected in compounding the mixtures:

natural rubber : 100 parts (30 gm.)
zinc oxide : 5 parts (activating agent)
stearic acid : 2 parts (dispersing agent)
Captax : 1 part (mercaptobenzothiazole, accelerator)
sulfur : 3 parts (vulcanizing agent)
filler : 0 to 60 parts/100 parts of natural rubber.

No anti-oxidant was added since the samples were tested 48 hours after mixing. The mixtures were all cured at 141°C. for 10, 20 and 30 minutes and, in each case, the optimum results are reported. The composition,

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[1] Taken from a thesis submitted to the Polytechnic School of the Free University of Brussels, Belgium in partial fulfillment of the requirements for the degree, Electrical and Mechanical Engineer, under the direction of Dr. W. De Keyzer (July, 1948).

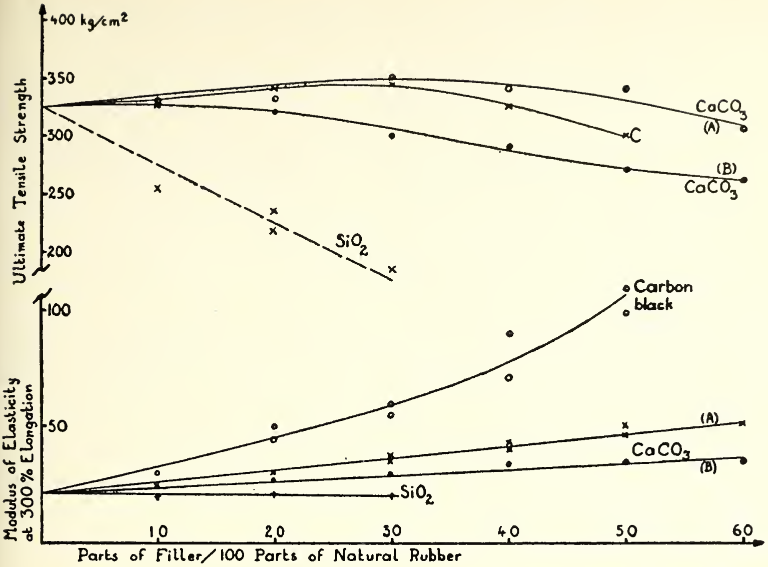

Fig. 1. The influence of different fillers upon the elastic modulus and ultimate tensile strength of natural rubber mixtures vulcanized at 141°C.

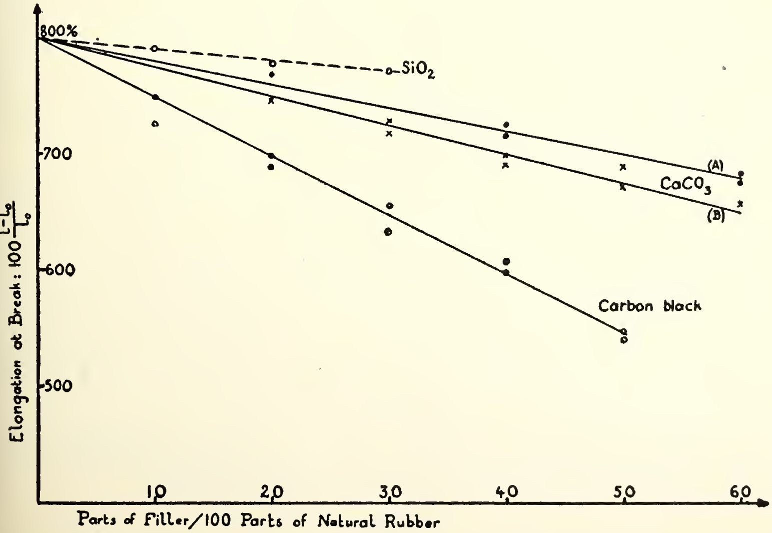

Fig. 2. The influence of different fillers upon the elongation at break of natural rubber mixtures.

time and temperature of cure of the mixtures are those usually selected and permit comparison with published results (10).

Preliminary Measurements: Sulfur and Carbon Black

To test the value of the testing method, a first group of mixtures containing 40 parts of carbon black and from 1 to 5 parts of total sulfur was tested. Linear relations were obtained between the total sulfur content and the elastic moduli and ultimate tensile strength. These results are similar to those reported by Barton and Hart (11).

A second group of mixtures, containing 3 parts of total sulfur as all the following ones, was then prepared with 0 to 50 parts of carbon black Micronex (average particle diameter: 28 $m\mu$).

The results are shown in Fig. 1 & 2: the ultimate tensile strength remains essentially constant, the elongation at break decreases rapidly with an increase in carbon black while the elastic modulus increases rapidly. The optimum vulcanization time was about 22 minutes. It is worth pointing out that the stress is calculated by dividing the load by the original cross-section whereas some authors calculate the actual stress by considering that the reduction in cross-section is directly proportional to the elongation. The results are in good agreement with those of Wildschut (10).

Calcium Carbonates

As pointed out before, ordinary calcium carbonate delays the vulcanization because of its basicity and the contact with the rubber is poor. By coating it with stearic acid, one obtains a product which is no longer wetted by water but which comes in good contact with the rubber through the organic tail of the acid.

The purpose of this investigation was to find a suitable substitute for the Japanese product available before the war (Hakuenka). The calcium carbonate designated as A was a commercial product while product B had been made in the laboratory. By inspection of Fig. 1 & 2, it is seen that the product A was somewhat superior to B as far as the mechanical properties were concerned. The optimum time of cure was about 8 minutes for A, 12 minutes for B and 17 minutes for an even rougher product C.

The correlation between good mechanical properties and low optimum time of cure lead us to conclude that the quality of the coating was involved since a poor coating would delay the vulcanization or cross-linking and give a poor contact between the filler and the rubber. However, other factors had not been considered at this point such as the size and shape of the particles. It is possible that calcium carbonate would be a better filler if obtained as aragonite needles rather than as calcite. Studies of the conditions of precipitation and studies of the crystalline structure by electron microscopy have since been published (2, 4).

The inert-filler behavior of calcium carbonate is shown by the above results: little variation in ultimate tensile strength, small increase in elastic modulus and small decrease in elongation at break.

Silica

Attempts were made, in Germany, during the war, to use colloidal silica as an elasticizing filler. The results that we obtained, using silica prepared by Mr. Pottier, seem to verify this possibility. In Fig. 1 & 2, one can see that silica hardly decreases the elongation at break (but an increase in elongation at break was sought), the elastic modulus decreases very slightly but the ultimate tensile strength decreases very rapidly.

However, in this case, the mechanical properties were found to increase nearly linearly with the time of cure. The optimum time of cure was not reached and must be 45 minutes or more. This bears out the fact that an uncoated acidic filler slows the cross-linking down and would justify an attempt to coat silica with a basic organic compound.

Stress-Strain Curves

Many expressions have been proposed for the mathematical representation of the stress-strain curves of rubber mixtures. Wildschut (10) proposes an empirical hyperbolic equation. Alfrey (1) takes crystallization into account. James, Guth & Mark established the expression:

$$\text{stress} = \text{KT}\left(\propto - \frac{1}{\propto^2}\right) \qquad \text{where } \propto = \frac{l}{l_o}$$

This expression is very satisfactory for soft rubber mixtures up to 350% elongation.

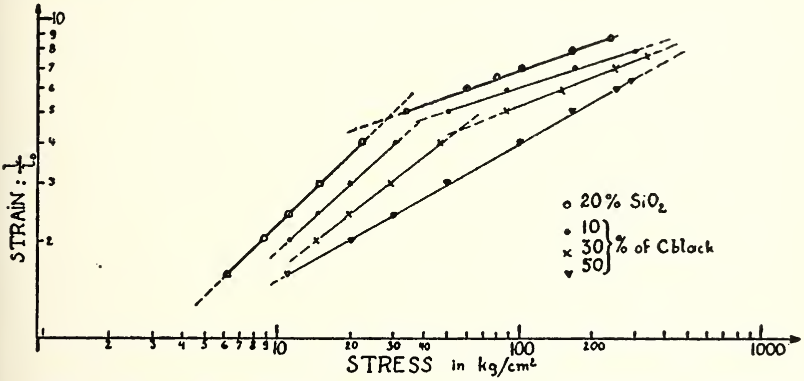

Fig. 3. Log-log plots of the stress-strain curve of rubber mixtures with different amounts of SiO_2 and carbon black.

By plotting all of our stress-strain curves in log-log scale, we found that they all presented the same appearance: i.e., two straight lines intersecting at sharp angle. In the case of mixtures with a high carbon black content, the angle was very small and one single straight line could be drawn. Four of these curves are plotted in Fig. 3, and it can be seen that the break between the two lines occurs in the range of 300 to 400% elongation ($\propto \doteqdot 4$ to 5).

This range has been reported by Hauser and Mark (1, 8, 9c), Goppel and Wildschut (10) to be the one in which crystallization takes place. Crystallization also occurs earlier in the case of mixtures containing carbon black. This can be shown by X-rays and by thermodynamical calculations.

It has also been reported (3, 6) that the tear resistance of rubber mixtures goes through a rather sharp minimum in the range of 250 to

350% elongation. We have verified those results for a mixture containing 40 parts of carbon black.

It appears thus likely that the crystallization of a large part of the rubber would account satisfactorily for the break in the stress-strain curve. The log-log plot has the advantage of putting this break sharply in evidence. Above this range, rubber mixtures will stretch up to 300% more (60% more than the elongation reached at the end of the crystallization).

We deal thus now with a crystalline phase with some amorphous material dispersed around the crystallites, it is thus normal for the crystallized rubber to behave as a fiber-like material of high elastic modulus and low extensibility which would be represented by the second straight line in the log-log plot.

Summary

A study of the reinforcing properties of carbon black Micronex, silica and two coated calcium carbonates in natural rubber mixtures was based on the mechanical properties of the compounded and vulcanized mixtures. The ultimate strengths, elastic moduli and elongations at break are reported.

Carbon black was found to be strongly reinforcing, causing a considerable increase in the elastic modulus and reducing the elongation at break. Calcium carbonate, coated with stearic acid, was found to be a satisfactory inert filler causing little variation in the mechanical properties. A commercial product (type A) was found to be superior to a laboratory product (type B): the poorer mechanical properties of the type B were accompanied by an increase in the optimum vulcanization time. This could have been caused by a less satisfactory coating but possibly also by different crystalline forms of the calcium carbonate.

Silica proved to slow down the vulcanization considerably. This is probably due to its acidity and would justify an attempt to coat silica in a manner similar to calcium carbonate. The results obtained with undervulcanized mixtures show that silica is somewhat of an elasticizing filler: decreasing the elastic modulus and the ultimate tensile strength without appreciable reduction of the elongation at break.

Finally, a log-log plot of the stress-strain curve shows a definite break corresponding to the range in which crystallization upon extension occurs. Rubber mixtures could thus possibly be considered as fibers of high modulus and low extensibility between 500% and 800% elongation.

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Some Analytical Uses of 3-Dimethylaminopropylamine[1]

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The determination of copper based on the production of the blue color of the copper-ammonia complex is among the oldest of all colorimetric methods. This procedure has been investigated extensively by Mehlig (2, 3), Yoe and Barton (4) and Yoe and Crumpler (5). The principal disadvantages of ammonia are its odor and volatility and the dependence of the color on the ammonia concentration (2, 4).

A number of reagents of moderate sensitivity have been suggested as substitutes for ammonia, among them being triethanolamine (4) and tetraethylenepentamine (1). These reagents are two to three and one-half times as sensitive as ammonia, are less volatile, and produce a color that is independent of the amount of amine in excess.

The possibility of using 3-dimethylaminopropylamine (N,N-dimethyl-1,3-propanediamine) as a colorimetric reagent for copper has been investigated as a portion of the study of metal chelate compounds.

Experimental

A Beckman Model DU spectrophotometer was used for all absorption measurements in this investigation. Matched cells of 1.00 cm. path length were employed.

Reagent or c.p. grade salts were used for the preparation of stock solutions. The copper (II) solution was standardized by electrodeposition and the nickel (II) solution by gravimetric determination with dimethylglyoxime.

Titration indicated a purity of 99.5% for the 3-dimethylaminopropylamine, Matheson No. 7148. Stock solutions were prepared by dissolving weighed portions of the amine.

In most instances precipitation of the hydroxide occurred upon addition of the amine to the solution of a metal ion. All solutions were therefore made 2.5 M in ammonium nitrate as a buffering agent.

The color of the solutions is stable for at least three weeks.

Effect of Excess Reagent

The optical densities of solutions in which the concentration of 3-dimethylaminopropylamine is increased with the copper (II) ion concentration fixed at 50 p.p.m. and at 200 p.p.m. show that color development is independent of excess amine at high concentrations. A plateau in the curve just before complete color development similar to that observed by Crumpler with tetraethylenepentamine and copper (II) ion was noted (1).

Conformity to Beer's Law

Conformity to Beer's law by the color system is shown by the fact that a straight line resulted when the optical densities at 595 mμ for

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[1] The writer wishes to thank the Research Corporation for a Frederick Gardner Cottrell grant-in-aid upon which the equipment used was purchased.

twelve solutions containing from 0 to 2500 p.p.m. of copper (II) ion were plotted against the respective concentrations.

Sensitivity of Color Reaction

A comparison of the sensitivities of a number of amines was reported by Crumpler (1). The specific extinction values [Extinction per centimeter per p.p.m. of copper (II) ion] at the wave length of maximum absorption are 0.00065 for ammonia, 0.0011 for triethanolamine and 0.0022 for tetraethylenepentamine. The corresponding calculations for 3-dimethylaminopropylamine give a specific extinction of 0.00084. It is seen that 3-dimethylaminopropylamine is approximately 1.3 times as sensitive as ammonia.

Use in Colorimetry

To prepare 50 ml. portions of colored solutions of the 3-dimethylaminopropylamine copper (II) ion with copper concentrations of 0 to 600 p.p.m., 10 ml. of 2% amine solution and 10 g. of ammonium nitrate should be used. For concentrations above 600 p.p.m. a greater amount of amine is necessary, about 1 ml. of 2% solution for each increment of 100 p.p.m.

The ions which interfere with this amine are those that interfere with ammonia (2). Nickel (II) ions have a greater effect than cobalt (II) ions, the reverse of their effect on the ammonia method.

Colored ions are formed by 3-dimethylaminopropylamine with nickel and cobalt ions, but the color intensity is low and therefore not promising for colorimetric purposes.

Summary

Copper may be determined colorimetrically by the use of 3-dimethylaminopropylamine provided a sufficient excess of reagent is used and ammonium nitrate is present in constant amounts to prevent precipitation of copper (II) hydroxide.

The ions which interfere with ammonia also interfere with this amine.

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The Alkylation Reaction of the Gabriel Synthesis[1]

John H. Billman and R. Vincent Cash, Indiana University

Although the usual procedure for the alkylation of phthalimide by the Gabriel (4) method has been to heat the organic halide with potassium phthalimide (or phthalimide plus potassium carbonate) to 170-200° for several hours, some attention has been given to the use of a solvent or liquid medium for the reaction. The use of such a reaction medium permits a lower reaction temperature and a shorter heating period, prevents overheating and browning of the product, and avoids caking of the reaction mixture in the vessel on cooling. Among the liquids employed as reaction media have been ethanol (1), methanol (8), acetone (2), toluene (6), xylene (5), and nitrobenzene (3)—the usual conditions being heating under reflux for periods as long as fifty hours. The best solvent seems to be dimethylformamide, suggested by Sheehan and Bolhofer (10), in which several N-substituted phthalimides were prepared in high yield by warming potassium phthalimide and the organic halide together for a short period.

We have found that dimethylformamide may likewise be employed for the reaction between phthalimide, anhydrous potassium carbonate, and the appropriate organic halide, according to the modified reaction of Ing and Manske (7). Thus we have prepared N-benzylphthalimide in higher yield and of greater purity than previously reported (9). In a similar manner we have obtained the new compound, N-hexylphthalimide, which completes the series of N-alkylphthalimides of ten or less carbons in the normal alkyl-group. Although unnecessary in the case of benzyl chloride, it was found advantageous to add a small amount of potassium iodide when the alkyl halide was a less-reactive bromide or chloride.

Experimental

N-Benzylphthalimide.—With provision for the exclusion of atmospheric moisture, a mixture of 14.7 g. (0.10 mole) of phthalimide, 7.6 g. (0.055 mole) of anhydrous potassium carbonate, and 19.0 g. (0.15 mole) of dry benzyl chloride in 40 ml. of dimethylformamide was heated at 140-145° for two and one-fourth hours. Little or no refluxing occurred, but carbon dioxide was evolved rapidly. The mixture was agitated occasionally.

After cooling, the reaction mixture was poured into 200 ml. of water. The solid which formed was collected upon a Büchner funnel and washed with successive 40-ml. portions of water, 2% sodium hydroxide solution, water again, and 50% ethyl alcohol. The air-dried, crude product weighed 20.4 g. (86.3%), m.p. 109-112°. Recrystallization from 95% ethyl alcohol provided 17.5 g. (73.8%) of colorless crystals, m.p. 115-116° (corr.).

N-Hexylphthalimide.—This preparation was similar to that above, substituting 24.8 g. (0.15 mole) of *n*-hexyl bromide for the benzyl chloride, and adding a few small crystals of potassium iodide. The material which separated upon pouring the reaction mixture into water was semisolid and oily in appearance, but could be collected after ice had been added to the water. Ice-cold washing solutions were used. Recrystallization was from ethyl alcohol, with the addition of water to the hot solution since the product is readily soluble in alcohol. After drying over calcium chloride in a small desiccator placed in the refrigerator, the yield of colorless crystals was 8.0 g. (34.7%), m.p. 37.5-38.5° (corr.). Further recrystallization did not alter this melting point value.

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[1] Contribution No. 577 from the Department of Chemistry of Indiana University.

Anal. Calcd. for $C_{14}H_{17}NO_2$: N, 6.07. Found: N, 6.08.

Summary

A new procedure has been developed for the preparation of N-alkylphthalimides.

N-Hexylphthalimide has been prepared for the first time.

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An Oscillographic Method for the Study of Solution Behavior at Radio Frequencies[1]

Robert B. Fischer and Dale J. Fisher, Indiana University

From a study of the analytical implications of solution theory, it was concluded that experimental data were required to determine what property of solutions in a high frequency electric field would be most suitable as an indicator property for analytical purposes. An oscillographic apparatus was designed and constructed for measuring both the dielectric constant and the conductivity of electrolyte solutions at radio frequencies. The method is applicable both with immersed electrodes and with non-immersed electrodes.

The behavior of solutions of electrolytes in a high frequency field is of significance from the analytical as well as from the theoretical standpoint. It is important to know how the dielectric constant, the conductivity and other related quantities vary with concentration in order that a wise choice may be made of an indicator property for analytical purposes. This subject is of interest in radio frequency extensions of conventional conductometric titrations employing immersed electrodes and also in ascertaining the true nature of the measurements in the newer field of high frequency titrations without immersed electrodes.

A study of the analytical implications of solution theory led to the conclusion that experimental data are required as a basis of this selection of the most suitable solution property. This conclusion is based upon the fact that theory is not well developed for solutions of concentrations commonly encountered in regular analysis and even for certain very dilute solutions.

Several methods, including the classical bridge methods, have been employed for evaluating the dielectric constant and the conductivity of electrolyte solutions, but these methods are generally of limited applicability. The Henriquez resonance method (6) (7), which has been adopted and modified by numerous workers (1) (2) (3), is useful for determining the dielectric constant of very low conductivity liquids. Methods developed by Drude employing immersed Lecher wires are useful for very high frequency investigations of conducting liquids; the Wyman modification (11) provides for such dielectric constant measurements of conducting liquids. Grubb and Hunt (5) have employed a grid dip method at about eighty megacycles in which immersed electrodes are connected to an inductance and tuned to resonance with a micrometer screw, thus measuring dielectric constants of solutions up to about 0.005 normal. Surber (10) has determined the dielectric constant of medium and high loss liquids at microwave frequencies with a variable length liquid column in a section of wave guide. Forman and Crisp (4) investigated energy loss and dielectric constant changes with concentration for a number of electrolyte solutions over a wide range of concentrations at wave lengths varying from 0.80 to 11 meters. The calorimetric method for measuring energy loss has been described further (9). Although these and similar methods have been very useful in some applications, it seemed that some other method would be desirable to provide simultaneous dielectric constant and conductivity measurements over wide ranges of electrolyte concentrations. The present study represents an attempt to develop such a method.

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[1] Contribution No. 576 from the Chemistry Department, Indiana University; abstracted from a part of the thesis submitted by D. J. F. to the Faculty of the Graduate School in partial fulfillment of the requirements for the degree, Doctor of Philosophy, 1951.

Description of Method

The phase difference between two sine wave voltages at high frequency can be measured with a cathode ray oscillograph, as discussed by Seely (8). The measurement is based upon the interpretation of the Lissajous patterns which result from the impression of two sine wave voltages of identical frequency across the two pairs of deflecting plates. This principle has been used in the present study.

The circuit diagram is indicated in figure 1. Figure 2 shows the equivalent circuit with immersed electrodes. In the apparatus as constructed here, a war surplus BC-457A transmitter, converted for operation from the 110 volt a-c lines, was used as the source at 4.5 megacycles. Resistor R is a plaque resistor, whose inductance was empirically compensated with mica and air condensers with the aid of a radio frequency bridge so that it is pure resistance (98 ohms) at the 4.5 megacycle frequency employed. A Dumont type 274 oscillograph was used with the input voltages applied directly to the deflection plates rather than passing them through the amplifiers first.

The Lissajous patterns were photographed with a Dumont type 314 Oscillograph-Record camera. Each complete photograph consisted of a triple exposure, one of the Lissajous pattern and one of each axis obtained by shorting the x and y input terminals in turn. A diagrammatic representation of the complete photograph is shown in figure 3 along with an identification of the quantities which are measured in this study. A is the distance from the origin to the intercept of the ellipse with the vertical axis, and e_2 is the maximum vertical deflection. Likewise, e_1 is the maximum horizontal deflection. The distances A, e_1 and e_2 were measured on each photograph (35 mm. frame) with the aid of the Wilder MicroProjector, model AM-20. Additional experimental quantities, R and ω (2 $\frac{1}{\pi}$ times the frequency) are constant for all measurements.

It is not, of course, necessary to follow all of these constructional and operational details completely in order to use the method presented in this study.

Analysis of Circuit with Immersed Electrodes

The cell employing immersed electrodes, figure 2, is considered to be electrically equivalent to a parallel r-C combination, and the numerical values of C and of r are the desired quantities. It is now necessary to derive the proper mathematical relationships between the measured quantities, A, e_1, e_2, R and ω, and the desired quantities, r and C. This may be done as follows. A graphical construction of the tracing shows that e_1 and e_2 are proportional, respectively, to the maximum voltages applied to

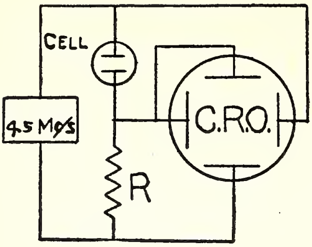

Fig. 1

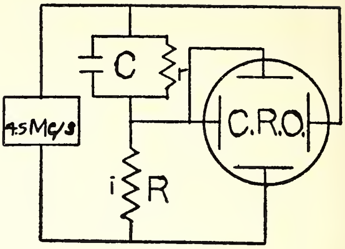

Fig. 2

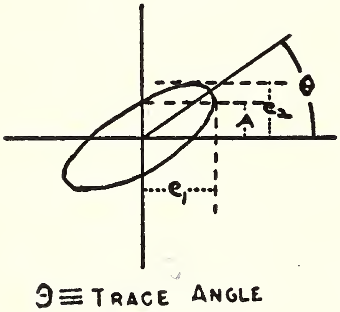

Fig. 3

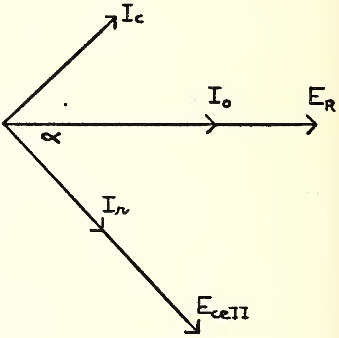

Fig. 4

the horizontal and to the vertical deflection plates. Because of this reason and the fact that the oscillograph amplifiers are not used, and assuming essentially identical deflection sensitivities (or correcting for specific sensitivities in tube employed),

$$\frac{e_1}{e_2} = \frac{E_{cell}}{E_R}$$ (in which E_{cell} and E_R are, respectively the voltages appearing across the cell and the resistor R of figure 1)

$$\frac{e_1}{e_2} = \frac{Z_{cell}}{R} \frac{I_{cell}}{I_R}$$

$$\frac{e_1}{e_2} = \frac{Z_{cell}}{R}$$ (since the same current flows through R and the cell)

$$Z_{cell} = \frac{Re_1}{e_2}$$ (equation 1)

The current through the cell must divide vectorially between r and C, so

$$\overline{I_{cell}} = \overline{I_r} + \overline{I_c}$$

$$\frac{\overline{E_{cell}}}{\overline{Z_{cell}}} = \frac{\overline{E_r}}{r} + \frac{\overline{E_c}}{\overline{X_c}}$$

$$\frac{1}{\overline{Z}_{cell}} = \frac{1}{r} + \frac{1}{\overline{X}_c}$$ (since the same voltage is across parallel parts of of the cell)

$$\frac{1}{Z_{cell}} = \sqrt{\left(\frac{1}{r}\right)^2 + (wc)^2}$$ (changing from vectorial quantities to quantities of magnitude only)

Rearranging,

$$Z_{cell} = \frac{R}{\sqrt{1+\omega^2C^2r^2}}$$ (equation 2)

Seely proves (13) that $\sin \propto\ = \frac{A}{e_2}$ (equation 3), in which $\propto$ is the phase difference angle between e_1 and e_2, i.e., between E_{cell} and E_R. A further relationship between $\sin \propto$ and the desired quantities, C and r, may be derived with the aid of the vector diagram, figure 4. Take the total current flow through R and the cell, I_c, as the reference vector. The same current flows through R and the cell, So I_R and I_{cell} are vectorially identical to I_o.

$$\overline{I_o} = \overline{I_R} = \overline{I_{cell}}$$

The voltage across R must be in phase with the current through R, since R is pure resistance at the frequency employed; thus the E_R vector lies along the reference vector. The currents through C and r are 90° apart, with I_c leading I_r, and these two currents must vectorially equal the total current through the cell. Furthermore, the voltage across the cell must be in phase with the current through its resistive component, so the vector for the voltage across the cell, $\overline{E}_{cell}$, must have the same direction as the vector $\overline{I}_r$. Angle $\propto$ is by earlier definition the phase difference angle between the voltages across the cell and R, so it is the angle indicated in figure 4 between $\overline{E}_R$ and $\overline{E}_{cell}$.

$$\cos \propto\ = \frac{I_r}{I_{cell}}$$ (from figure 4)

$$\cos \propto\ = \frac{\dfrac{E_r}{r}}{\dfrac{E_{cell}}{Z_{cell}}}$$

$$\cos \propto\ = \frac{Z_{cell}}{r}$$ (since E_r and E_{cell} are equal)

Substituting equation 2, $\cos \propto\ = \frac{1}{\sqrt{1+\omega^2C^2r^2}}$

But, $\sin \propto\ = \sqrt{1 - \cos^2 \propto}$

So, $$\sin \propto\ = \sqrt{1 - \left(\frac{1}{\sqrt{1+\omega^2C^2r^2}}\right)^2}$$

$$\sin \propto\ = \frac{\omega Cr}{\sqrt{1+\omega^2C^2r^2}}$$ (equation 4)—

Combining equation 1, 2, 3, and 4 and solving for C and r, the following equations are obtained:

$$C = \frac{A}{e_1 R \omega} \qquad \text{(equation 5)}$$

$$r = \frac{\frac{e_1}{e_2} R}{\sqrt{1 - \left(\frac{A}{e_2}\right)^2}} \qquad \text{(equation 6)}$$

Equations 5 and 6 relate the desired quantities, C and r, to the experimentally measurable quantities, A, e_1, e_2, R and ω. It should be emphasized that the significance of C and of r is this: a pure capacitance and a pure resistance of these magnitudes, when connected in parallel and substituted for the cell, would result in a phase difference the same as that observed experimentally with the conductivity cell. If the assumption of the equivalent circuit, figure 2, is correct, the magnitudes of C and of r are directly proportional to the dielectric constant and the resistance, respectively, of the solution combined with the particular sensing element and linking field used. This assumption may be supported by the experimental results obtained upon solutions of known properties.

Analysis of Circuit with Non-immersed Electrodes

With non-immersed electrodes as in the new type of high frequency methods of analysis, the equivalent circuit is the same as that in figure 2 with an additional capacitance, C_g, in series with the parallel r-C combination. The measured quantities, A, e_1, e_2, R and ω, must be related mathematically to the quantities C_g, r and C of the equivalent circuit of the cell. Then the value of C_g must be measured experimentally (e.g., by filling the cell with mercury and measuring its capacitance with a conventional capacitance bridge—this is, in effect, shorting the r-C portion of the equivalent circuit of the cell so that the C_g factor represents the entire cell). Although this derivation need not be carried through here, it may be performed by rewriting the C_g, r and C quantities into an equivalent parallel resistive-capacitive impedance and then proceeding as in the case of immersed electrodes.

Conclusions

The error in this type of measurement may be as much as two or three per cent because of several factors: the pairs of deflecting plates may not be exactly at right angles to each other; curvature of outer deflection field regions; non-linear responses of deflection; random errors in measurement of the several quantities on the photographed pattern; non-uniform film shrinkage.

This apparatus has been constructed and tested experimentally. The experimental data have served to show the feasibility of the method if stray reactances are minimized to a readily obtainable degree.

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A SYMPOSIUM

The Relationship Between Teaching of Chemistry in the Secondary Schools and in the Colleges and Universities of Indiana

INTRODUCTION

EDWARD L. HAENISCH, Wabash College

The problem of supply and demand for chemists has received much attention recently, including a special symposium at the September meeting of the American Chemical Society in Atlantic City. Rather startling were the statistics released by the Society that in 1954-55 only 5,000 will receive bachelor's degrees with a chemistry major in contrast to 11,000 in 1949-50. There is some evidence that percentage wise of the total college enrollment chemistry is holding its own but industry and government have greatly expanded their needs in the last decade.

It is recognized that vocational guidance programs must start early, certainly at the secondary school level and perhaps even in the primary grades. The remarkable surge in freshman engineering registration this fall proves the usefulness of a "grass-roots" selling program. Much must be done to aid the secondary school chemistry teachers, especially those in the smaller high schools who have to teach many subjects and who may not be adequately trained in chemistry. A number of interesting facts concerning these teachers were published by Professor Watson of Harvard University in the September 5, 1952 issue of *Science*.

Much has been accomplished by the American Chemical Society with its revitalized vocational guidance program and its participation in general manpower studies. A number of the local sections of the Society has devised special methods of cooperation with the schools in their areas. Associations like the New England Association of Chemistry Teachers with its monthly reports in the *Journal of Chemical Education* or the Northeastern Ohio group to be described later in this symposium, have been very helpful. Science Talent Search, state science fairs and other such activities play an important part in stimulating interest.

Work of the Northeastern Ohio Chemistry Teachers Organization. E. EUGENE WEAVER, Wabash College.—Northeastern Ohio Chemistry Teachers Organization was formed December 12, 1925 by a group of high school chemistry teachers who were attending a teachers' convention. The group was called together by Vernon S. Culp who was a chemistry teacher in West High School, Akron. NeoChemto, from the beginning, included chemistry teachers from high schools in Cleveland, Akron, Canton and Medina; and from the colleges of Oberlin, Baldwin-Wallace, Hiram, Wooster, Western Reserve and Kent State.

Meetings were held twice yearly on a Saturday, usually on one of the college campuses. The program often consisted of a trip through one of the local industries in the morning followed by a group luncheon; the afternoon was devoted to a talk by local faculty member or, more often, a panel discussion on some common problem of the group.

Such an opportunity for an exchange of ideas about, and constructive criticism of, our high school and college programs seems to be lacking in Indiana. As desirable as such an organization would be, it would be extremely difficult to start without the full-fledged support of the high school teachers. Since the trend seems to be for the high school chemistry teacher to frequently have a college major in a field other than chemistry, professional interest in such an organization is not likely.

The success of NeoChemto was dependent upon: the fact that there was an awakening in the field of chemical education, the interest and activity of the high school teachers, and the realization that the two groups had common problems which could best be met by working together.

Preparation for college chemistry. F. C. SCHMIDT, Indiana University.—Perhaps more important than a previous training in High School chemistry as a preparation for the beginning course in College General Chemistry is a thorough training in High School algebra and a year of physics.

By means of a series of tests over the last four years based on the mathematical manipulations employed in the first year of college chemistry, we at Indiana University have found that the students coming in are woefully lacking in the ability to use logarithms, handle exponentials, and solve quadratic equations. We have been forced to require the student taking General Chemistry to take college algebra as a prerequisite or concurrently, if he has not presented four half-years of algebra for admission to the College.

Counsellors in the High Schools should advise those students contemplating work in science in a college to take two full years of algebra. Such advice would save the student 5 hours which he could use in other studies.

Findings of a Purdue committee on how to stimulate interest in young students to choose a career in chemistry. ROBERT A. BENKESER, Purdue University.—A recent survey showed that during the past three years fewer than 0.4% of the entering freshmen at Purdue University were graduating with B.S. degrees and a chemistry major. Accordingly a committee in the chemistry department was appointed to study this rather alarming situation since the rapid growth of Chemical Industry was causing an increased demand for scientifically trained college graduates.

The committee report listed five major reasons for the decline of college science enrollments. 1.) Students today are choosing easier fields in which to major in college. 2.) A rumor persists that chemists are underpaid. 3.) Students feel that a successful career in chemistry necessitates obtaining an advanced degree. 4.) Small high schools seldom have adequate laboratory facilities for chemistry. Hence much of the stimulation and interest that can be aroused in the chemical laboratory is lost. 5.) Many of our high school teachers are overburdened by teaching other courses in addition to chemistry.

As a partial remedy for this situation the committee suggested that the chemistry department at Purdue hire a full-time man whose principal job would be to act as a liaison with the Indiana high school chemistry teachers. In essence they would act as a team to stimulate interest in chemistry in students at the high school level. Secondly, this "sales program" might also be extended to the colleges. In this regard Purdue is contemplating a "high school day" to be sponsored at least in part by the chemistry department. A program would be planned so as to stimulate latent interests in these students to choose chemistry for their career.

Comments on teaching chemistry in high school and college. NED GUTHRIE, Hanover College.—From my work during some twenty summers in the registrar's office of Hanover College I have observed that students take less mathematics, bookkeeping, physics and foreign language in their high school course. They have more credits in general business, music, art, social studies, health, safety and physical education. The following table shows the per cent of all students in Hanover College during the years indicated who presented entrance units in the sciences listed:

	1933-34	1937-38	1941-42	1952-52
Physics	46	41	35	35
Chemistry	35	41	45	46
Biological Science	68	68	70	82
General Science	16	14	16	18

Only thirty per cent of the entering freshman class of 1952 at Hanover College took physics in high school while thirty-seven per cent took more than one year of algebra in high school.

Many of the smaller high schools do not have adequate laboratory equipment for teaching any science. Some have group work instead of individual laboratory work while some have only demonstrations by the teacher. Some substitute movies for laboratory work. There is no uniformity of content in the chemistry course of the high schools. There is too much memorizing of facts with insufficient understanding of the scientific principles involved. There is also the tendency to avoid those subjects which are considered difficult. It is necessary to consider these factors in teaching the first course in college chemistry.

In some fifteen states where I have made out applications for teaching certificates or licenses, it is possible to obtain a teaching license in chemistry in all of them by taking from fifteen to eighteen semester hours work in chemistry. Permits require even less chemistry. Data collected for three periods of five years each show that two-thirds of those preparing for high school teaching rank in the middle third of their college class while the remaining third were equally divided between the upper and lower thirds of their college class. This indicates that high school teaching does not attract the best students. Far too many teachers take a master's degree in education rather than additional training in the sciences. Seven of my students who are teaching chemistry in high school have taken a master's degree in education while only one took a master's degree in chemistry. We would have better teaching of chemistry in the high school if we required more training in chemistry, physics, mathematics, geology, botany and zoology. Most high schools lack funds for purchase of laboratory equipment and many teachers lack time and ingenuity for making laboratory equipment. I am not advocating that a master's degree in chemistry should be required in order to teach the subject in high school or to receive a life teaching license or certificate. Considerable training beyond the fifteen to eighteen semester hours in chemistry should be required as well as additional training in other sciences. This is probably more valuable to the student than to require the teacher to earn a master's degree.

If we could start a science curriculum with the first grade, it would be much easier to teach chemistry and other sciences in high school and college. A six-year-old child has the natural curiosity for the study of science and has not been spoiled by too much memory work. We cannot make scientists of all, nor do we want to do so, but we can interest young people in science, give them a better understanding of science and an appreciation of science. Since we are living in a scientific environment, such training will enable them to become better citizens. We need a suitable curriculum, suitable laboratory facilities and competent teachers.

Comments by a secondary school teacher. E. WAYNE GROSS, University School, Indiana University.—The colleges and secondary schools have a common interest in the education and development of the student. Many problems and conflicts arise in this development. Discussion and clarification of these problems is needed for their solution.

Chemistry as a course in the small high school is being examined closely. Better techniques and materials in the course are needed. One suggestion for the small school is the alternation of physics and chemistry.

The teacher preparation program must be improved if the teaching is to be improved. The college chemistry departments can help in this task by providing opportunities for teachers and professors to talk over their mutual problems.

Another mutual problem is the education of the gifted student. All too often, they are neglected. The secondary schools and colleges should work together to capitalize to the fullest extent on the students that are, or may be, interested in science.

ENTOMOLOGY

Chairman: F. N. YOUNG, Indiana University

M. CURTIS WILSON, Purdue University, was elected chairman for 1953

ABSTRACTS

Some little known habits of the insects which "catface" peaches. G. EDWARD MARSHALL, Purdue University Agricultural Experiment Station, Orleans, Indiana.—Field studies in 1952 indicate that there is little cessation in the rate of attack by the Pentatomid bugs which "catface" peaches from the time they start feeding during the balloon stage of the blossom in the spring until harvest. Physical changes in the peach fruit itself occur in stages, from the time the ovule is fertilized until harvest. These changes have obscured and complicated the identification of injury to peaches by Pentatomids. To facilitate an understanding of the condition of the fruit and what takes place during bug attacks as the season advances five stages of the peach fruit have been designated as the season progresses: (1) Dehiscense, (2) Fuzz removal, (3) Wax pedicel, (4) Brown spot, (5) Fruit ripe.

Control of the cabbage maggot, *Hylemya brassicae* (Bouche). GEORGE E. GOULD, Purdue University.—The cabbage maggot, the larval stage of the fly *Hylemya brassicae* (Bouche), is a serious pest on all crops of the family Cruciferae. The larvae feed on and often destroy the roots of cabbage, cauliflower and kale and in addition tunnel on the surface of turnips and radishes. Damage was especially severe in 1951 and 1952 with losses as high as 50 to 75 per cent of the crop. Heaviest losses occurred on those crops grown in the spring and fall in those areas where extensive acreages of vegetable crops were grown. Commercial vegetable growers of Marion and Lake counties have suffered the greatest losses, while some damage in home gardens has been reported from all parts of the state.

Several of the new insecticides have shown promise in the replacement of the corrosive sublimate method of drenching the plant roots. The more promising of the new materials include chlordane, aldrin, and Heptachlor. Several methods of applying these materials have been tested and the following gave good to excellent results on cabbage: dipping roots in emulsion before transplanting, dusting roots before transplanting, using insecticides in transplant water, drenching soil around newly set plants, and dusting or spraying newly set plants three times at weekly intervals. The dip method was found to be the simplest, as here the grower can pull his plants, dip the roots in the emulsion and set in the field. It was noted that dipped plants were slower in starting to grow, but after two months were larger and had more mature heads than the untreated plants. Many commercial growers in the vicinity of Indianapolis have used the dip method with chlordane as the insecticide and have had over 98 per cent of their plants maggot-free.

Results on tests to control this same maggot on turnips and radishes have not been satisfactory. Soil treatments and insecticides in the row before planting had little effect on subsequent maggot populations, while dust and spray applications to young plants gave only temporary protection. Indianapolis growers of fall turnips have avoided serious losses by planting in fields several miles away from the commercial gardening area.

Notes on the distribution and habitat of *Agabus confusus* (Blatchley). (Coleoptera: Dytiscidae). Doris R. Kline, Indiana University.—*Agabus confusus,* described from a single specimen as *Rhantus confusus* by W. S. Blatchley, is relatively rare in collections, and nothing seems to be known concerning its habits or habitat. The species has been found in Monroe and Brown counties, Indiana and in Jefferson County, Kentucky. Adults were found in association will small, intermittent streams in both limestone and sandstone regions. They were rarely seen in water, but were found in moist situations under rocks in nearly dry stream beds or near pools left when the streams dried up. All streams along which the beetles were found are in wooded areas and show little silting and no aquatic vegetation or decomposed organic matter. No larvae have been found to date. Observations on specimens in aquaria indicate that they may be more active at night.

Differential selection of mating and oviposition sites in *Perithemis tenera* Say, classed according to degree of wing pigmentation (Odonata). Merle E. Jacobs, Indiana University.—The selection of mating and oviposition sites in males and females of the highly polymorphic species, *Perithemis tenera* Say, was studied in the field by means of individually marked specimens. Individuals observed repeatedly showed a high degree of constancy in regard to whether they selected floating wood or mats of vegetation as mating and oviposition sites. Of 653 females divided into eight classes according to the degree of wing pigmentation, the percentage of each class ovipositing on floating or projecting wood, sticks, or logs was as follows:

1 (lightest)	2	3	4	5	6	7	8 (darkest)
33%	35%	38%	51%	62%	58%	69%	100%

Of 460 males divided into three classes, the percentage of each class selecting mating sites on or about floating or projecting wood, sticks, or logs was as follows:

1 (lightest)	2	3 (darkest)
32%	39%	71%

The Approach to Taxonomic Problems[1]

FRANK N. YOUNG, Indiana University

Of all the large family of zoologists the entomologist, who calls himself a taxonomist, has won the firmest place in the public mind as a simple minded eccentric. He is the character who is continually being caricatured as dashing madly across the fields, butterfly net in hand and goatee rampant. It is to him also that we owe the definition of entomology as that science which consists of moving insect pins from one place in a box to another. This popular stereotype of the taxonomist has come about through a misunderstanding of what taxonomists do and the purposes behind their work. It is also the outgrowth of the personality of individuals, whom we associate with taxonomy, and about whom various wild and unprovable tales have grown up. It is useless to deny that a certain percentage of taxonomists are queer ducks, but it is unfortunate that we seldom hear about those who seem to be normal.

In the early days of entomology in this country, the objectives of the few taxonomists, who had the inclination and courage to attempt the classification of our vast insect fauna, were quite different from those of workers in the same field today. Many of the early workers were firm believers in special creation of species and to them their task was simply to produce catalogues of existing and immutable entities. Later evolutionary theories influenced various workers, and many of the abuses which we lay at their feet were the result of attempts to extend the methods of classical descriptive taxonomy into areas where they could not be applied. Right down to the present, the principal tool of taxonomic entomology regardless of its purposes has been pure intuition. The primary difference between the older taxonomists and modern workers is neither in purpose nor method, but in the belief that intuition is the beginning, not the end, of taxonomic study.

Taxonomy can be defined as the systematic study of the nature and relationship of naturally existing species populations. By such a definition, it falls somewhere between descriptive and experimental morphology and population ecology. In other words, we are dealing with organisms above the level of the individual, but not quite at the level of the biotic community. The principal common ground among taxonomists in all fields lies in their interest in distribution, variation, adaptation, relationships, and inheritance as they affect species populations rather than individuals.

Such an approach is not always regarded with favor. The results of such studies do not always seem worthwhile to everyone. It is argued that the same results could be obtained by the systematic exhaustion of other fields such as morphology, genetics, ecology, and biogeography. Against this argument the tremendous abundance of existing forms of insects, not counting the extinct forms, is a primary objection. Assuming that one person in his lifetime could exhaust one of the special fields such as genetics for each species, it would require about 25,000 individuals to complete the study of Coleoptera alone in North America, north of the Mexican boundary. One of the great contributions which taxonomy can make is the discovery of points at which studies in other fields can be started with a maximum promise of results applicable to groups rather than individual forms. It is the old argument of strategy versus tactics.

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[1] Contribution No. 514 from the Department of Zoology, Indiana University.

There seem to be three main steps in approaching any taxonomic problem. The first is still the "intuition" of the older workers, involving the selection of a problem which offers possibilities. There may come a day when intuition is no longer needed, and the routine application of statistical methods carried out by batteries of workers feeding data into machines will make any problem worth attacking. Such a time seems, however, very distant when we consider the number of workers and the financial arrangements under which most of them proceed. The second step is the hard part. It involves subjecting our initial intuitions to the most detailed sort of analysis, attempting to make our data quantitative, and by painstaking and tedious work to remove as much of the subjective element as possible. Here the battery of workers and machines would be most useful, but in itself this sort of detailed analysis can produce little beyond an accumulation of facts. It requires a third step in which by induction we attempt to bring back into focus our original problem and by correlating all the available data arrive at a more complete solution. Here we must call upon every available source of information be it from genetics, ecology, palaeontology, geomorphology, or history to complete our picture.

There are many fine examples of entomological problems which have been conceived and carried out in just such a fashion. I would like to present as an illustration, however, an incomplete problem from my own field, primarily because it points up many of the difficulties to be encountered.

The Background: Thomas Say in 1823 first recognized as distinct from other known forms a group of predaceous water beetles which he described as *Colymbetes bicarinatus*. His description is very meager, but he pointed out various salient features which allowed the ready recognition of the group to which Aubé in 1838 applied the generic name, *Matus*. Thus matters stood for 102 years, until Hugh B. Leech, now of the California Academy of Sciences, took the trouble to look at some of his specimens from various parts of the United States and discovered the surprising fact that *Matus bicarinatus* (Say) was really a complex of related forms rather than a single widespread species. The same year that Leech's paper redefining Say's *bicarinatus*, and describing a new species with a distinct subspecies from northern Florida and Georgia, was published, I discovered a remarkable pygmy species of *Matus* in western Florida. Later another distinct species was discovered in eastern Texas and Arkansas.

In a relatively short period, following the initial recognition of the composite nature of the genus, four distinct populations which we can call species, and a fifth population which we consider a subspecies, have been recognized. It is not hard to understand why these populations remained so long unrecognized when forms of far less distinction in other groups were well known. *Matus*, as a genus, is beautifully characterized by the sulcate prosternum, tarsal claws, and body shape, and the several species bear a remarkable superficial resemblance to one another. Further, the forms are highly seasonal in occurrence as adults, which makes them rare in collections, and no one apparently had ever looked at more than a few specimens at one time from different places. Even now the male genitalia are the best indicators of the distinctions, and must often be relied on for recognizing the overlapping populations.

The Problem: Now that we have a number of recognizable populations within the genus *Matus*, we can attempt the formulation of a problem which will take advantage of the peculiarities of the group. *Matus* is presumably a relict of the ancient woodland fauna of the Appalachian region. It is confined to the Eastern United States and the various forms are distributed peripherally around the mass of the Appalachian Mountains. Its only relatives are found in Australia, so that we have a striking example of a group of organisms isolated in time and space, and thus presumably of very ancient origin. What can we hope to learn from a study of the existing populations of *Matus?* Half a dozen answers immediately occur to me, but most of them are not directly approachable by taxonomic methods. The immediate taxonomic problem seems to be a study of the population structure of the various forms making up the genus and a comparison of this structure with that of genera which are undoubtedly more recent in origin, less specialized, and show different patterns of distribution.

The Analysis: So far, the analysis of the various populations of *Matus* has not progressed very far. There is still a dearth of specimens available for study, and the accumulation of series of specimens from different localities is a painstaking process. Some interesting facts have already appeared, however, the most promising being that even the described "species" are not uniform. Characters which we consider diagnostic slide up and down scales of variation, biometrical characteristics shift over large areas, and isolated populations present new and undescribed differences. It will be many years before necessary facts for a complete taxonomic analysis can be accumulated.

The Inductions: With the analysis of the populations still incomplete, only tentative conclusions are possible, but several general hypotheses may be of interest. It seems very probable that the genus *Matus* existed long before the Pleistocene in North America, and that by the beginning of the ice age it was already differentiated into distinct "species" of which at least two survived in the Appalachian region. With the spread of the glaciers the populations of these forms spread south and in places were isolated on the Pleistocene islands of Florida and probably elsewhere along the Gulf Coast. The isolation seems to have been partly due to geographic and partly to ecological factors. Many of these isolated populations still exist, and the study of the relationships of these relict forms to one another promises basic data for evolutionary and ecological theory.

In conclusion, I would like to say that I hope that I have made the point that modern taxonomy offers a worthwhile way of looking at biological problems. It is not entirely the "cut and dried" process of describing new species, preparing keys, and making determinations, but involves the consideration of data from many other fields and promises starting points for many other kinds of investigation. "Intuition" still plays a large part in taxonomy, but the results of intuition should be the beginning not the end.

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Insects of Indiana for 1952

John J. Davis, Purdue University

The 1952 season was marked by periods of extremes in temperature and rainfall which had a marked effect on the abundance of some insects and scarcity of others.

The month of May was normal or below normal in temperature, but high in precipitation. June was noticeably above normal in both temperature and precipitation. July was rather dry and with a rather high average temperature. August and September were about normal for both temperature and precipitation, while October was below normal in both temperature and precipitation.

Field Crop Insects

European corn borer *(Pyrausta nubilalis* Hbn.) was of little importance in 1952. The borers passed the winter of 1951-52 in few numbers, and although there was more than normal acreage of corn planted early, that is, before our recommended date for corn borer prevention, the first generation of borers did not develop to serious numbers. Also, although there was a considerable acreage of late planted corn, which normally would be favorable for the second generation of borers, weather conditions were unfavorable for the borer and no appreciable damage resulted. At present, all indications are for a small overwintering population. (Recent survey shows 39 borers per 100 stalks, compared to 68 last fall, although a large percentage were immature last year and would not pass the winter safely, while in 1952 most of the borers are fully grown.) Even so, if conditions are favorable and we have a large acreage of early planted corn in 1953, a destructive population may develop.

The chinch bug *(Blissus leucopterus* Say) again threatens the grain and corn crops of Indiana. In 1951 there was a noticeable increase, especially in northeastern Indiana, but not much damage resulted. However, in 1952, beginning the first of July, calls began coming in and considerable damage to corn resulted in spite of some early heavy rains. Doubtless the rains did destroy many of the bugs, but were not adequate to completely control them. The hot, dry weather the last half of June favored the bugs that survived the rains. As a result, chinch bugs were common in the eastern two tiers of counties from Randolph County on the south to Steuben County at the Michigan state line and caused considerable loss to corn. At present, conditions are favorable for a large carry over and likely abundance in 1953.

The black or greasy cutworm, also known as the overflow worm *(Agrotis ypsilon* Rott.) was a major pest throughout the northern half of the state during the first half of July, destroying thousands of acres of corn. During the last half of May it was abundant and destructive along the Wabash and White rivers in southwestern Indiana. This species is common in that area following late overflows. Apparently the moths from this early generation migrated north and hit the northern half of the state in July following heavy rains which provided favorable conditions for egg laying such as occur in the southern part of the state following late overflows. Soybeans were also severely damaged.

Grasshoppers *(Melanoplus differentialis* Thos. and *M. femur-rubrum* De G.) were abundant in southern Indiana and during the early part of July moved into cultivated fields causing much damage. During August they continued abundant and caused rather serious damage to tomatoes by eating into the fruits and at a time when canning tomato harvest was at its peak. During September they appeared in the northern part of the state and caused severe losses to young alfalfa.

Corn rootworm *(Diabrotica longicornis* Say) was serious, causing lodging of corn even as early as August, in areas of central Indiana where corn had been grown continuously on the same ground for three or four years.

Corn leaf aphid *(Aphis maidis* Fitch) was exceedingly abundant in southern Indiana during August, but there was little evidence that it was causing much damage excepting in the drought areas where aphis abundance increased the seriousness of drought.

The corn earworm *(Heliothis armigera* Hbn.) developed a heavy infestation in southern Indiana in late June and was moderately severe farther north later in the season.

Sod webworms *(Crambidae)* were unusually abundant in southeastern Indiana causing noticeable losses to corn.

Flea beetles, especially the corn flea beetle *(Chaetocnema pulicaria* Mels.), was destructive to small corn in central Indiana early in the season.

Hessian fly *(Phytophaga destructor* Say) infestations were generally light over the state. There was a tendency for moderate to heavy infestations in the southwestern region, and spotted moderate to heavy infestations in some other areas of the state.

The wheat jointworm *(Harmolita tritici* Fitch) was generally light or spottedly heavy with the exception of the northwestern region which showed average moderate to heavy infestation. Only a few cases of itch mite *(Pediculoides ventricosus* Newp.) were reported, which was to be expected with the decrease in abundance of jointworm and Angoumois grain moth, two principal hosts of the mite.

Clover leaf weevil *(Hypera punctata* Fab.) was more abundant than usual in the southern half of the state and most reports referred to abundance on clover.

Clover budworm *(Hypera nigrirostris* Fab.) was abundant and destructive in central Indiana, destroying the new shoot buds of clover.

Clover root curculio *(Sitona hispidula* Fab.) began emerging in unusually large numbers in northern Indiana August 25, indicating the importance of this pest.

The pea aphid *(Macrosiphum pisi* Kalt.) was exceptionally abundant and destructive to alfalfa in the southern third of the state the last half of April. This situation may be attributed to the cool weather which checked the parasites that would have otherwise held the aphids in check.

The common spittlebug *(Philaneus leucophthalmus* L.) has been on the increase for several years. It was first conspicuously abundant in northern Indiana about seven years ago, but is now destructive throughout the state, being especially damaging to clover, alfalfa, and strawberry. This year they began hatching April 7 in southern Indiana, and at Lafayette April 17, about two weeks earlier than usual.

The alfalfa plant bug *(Adelphocoris lineolatus* Goeze) became conspicuously abundant in the northern half of the state by July 10. At that time most of the insects were nymphs.

Potato leafhopper *(Empoasca fabae* Harr.) was exceptionally abundant during July, particularly on potatoes, beans, and alfalfa.

Vegetable Garden Insects

Wireworms *(Elateridae)* caused much damage to potatoes and most of our records and observations came from the muck areas in the northern half of the state. Some damage to corn was reported.

Tomato hornworms *(Protoparce sexta* Johan. and *P. quinquemaculata* Haw.) appeared rather suddenly in very large numbers early in September, causing considerable damage to canning tomatoes by eating into the ripening fruits. They appeared to be most prevalent in central Indiana.

Blister beetles, especially the striped species *(Epicauta vittata* Fab.), were general and abundant during August, attacking vegetable crops, especially potato and tomato, and flowering plants.

The Colorado potato beetle *(Leptinotarsa decemlineata* Say) was more than usually abundant the last of June and early July.

Rose chafers *(Macrodactylus subspinosus* Fab.) were very abundant in many parts of the state, perhaps more so in the northern half, early in June, attacking a variety of crops.

Cabbage maggot *(Hylemyia brassicae* Bouche) caused 40-50 per cent loss of untreated early cabbage and cauliflower, and as high as 90 per cent loss of late turnips in some fields in the vicinity of Indianapolis.

Turnip aphids *(Aphis pseudobrassicae* Davis) were very abundant on late turnips.

The rhubarb curculio *(Lixus concavus* Say) was the subject of inquiries from all parts of the state and in general, punctures in stalks were so numerous as to ruin them for use.

Fruit Insects

Codling moth *(Carpocapsa pomonella* L.) is no longer a problem of the apple grower in Indiana, since the introduction and general use of DDT. Ten years ago the codling moth was the major problem discussed in fruit growers' meetings. Now it is seldom referred to. However, as has been noted before, the use of DDT has been largely responsible for the increase of other problems, such as the European red mite and red-banded leafroller.

The apple maggot *(Rhagoletis pomonella* Walsh) is more or less of an annual pest in the two northern tiers of counties, and until this year has never occurred, according to our records, south of Fort Wayne. In 1952 it was reported very abundant in Morgan County, south of Indianapolis, and the reporter indicated it had been increasing for several years.

The cherry maggot *(Rhagoletis cingulata* Loew) was again reported as destructive in several areas in the northern tier of counties. It will be recalled that reports were received in 1951, the first reports for a number of years.

The periodical or 17-year cicada *(Magicicada septendecim* L.), which appeared in great abundance throughout the state in 1936, is due in 1953. This is the major brood occurring in Indiana.

Insects of Trees and Ornamentals

Pine sawflies, particularly *Neodiprion sertifer* Geoff., has been on the increase in Indiana, especially in the northern half of the state, for the past several years. The past year considerable acreages of pines, including reforestation and Christmas tree plantings, were partially to completely defoliated. Perhaps the increase in plantings of pine is largely responsible for sawfly increase. It is suggested that in old plantings as trees are removed the removal be done so as to leave roadways to permit use of spray equipment, and for the same reason that new plantings be made to provide roadways.

Walking sticks *(Diapheromera femorata* Say) again defoliated acreages of trees, principally scrub oak, near Walkerton. In this same woodlot of perhaps 40 acres, they have been more or less abundant for a number of years.

The elm leaf beetle *(Galerucella xanthomelaena* Schrank) was abundant in many sections of the state, especially in the southern half. Based on reports received, it was more abundant than usual.

Bronze birch borers *(Agrilus anxius* Gory) were the subject of an unusual number of inquiries during the first half of September. Perhaps dry weather during the past season has been responsible for the more than usual cases of dying branches.

Bagworms *(Thyridopteryx ephemeraeformis* Haw.), which has been a predominant pest for several years but showed a decrease in 1951, was conspicuous by its absence in 1952.

The canker worm *(Paleacrita vernata* Peck) was reported from a number of localities indicating that it may be returning as a serious pest.

The cottony maple scale *(Pulvinaria vitis* L.) was very abundant in some areas in northern Indiana.

Azalea mealy bug *(Eriococcus azaleae* Comst.) was abundant on azalea in central Indiana.

As usual, many different galls were submitted for identification, doubtless because of their conspicuousness. As in years past, the one most commonly sent in is the maple bladder gall *(Phyllocoptes quadripedes* Shim.) which is caused by a mite.

Household and Miscellaneous Pests

Houseflies *(Musca domestica* L.) were more abundant than for a number of years. Also greater difficulty was experienced in control with the new organic chemicals. Perhaps the fact that flies were more abundant than usual minimized the value of sprays.

Mosquitoes were excessively abundant during the past season.

The clover mite *(Bryobia praetiosa* Koch) was the subject of many inquiries from all parts of the state during May and June, invading homes and becoming annoying.

The common dog tick *(Dermacentor variabilis* Say) was more abundant than usual and during the spring months reports were received from all parts of the state.

Carpenter bees *(Xylocopa* sp.) were reported abundant from many places in the state and in some cases they were damaging to structural timbers as well as being annoying.

The subterranean termite *(Reticulitermes flavipes* Koll.) was abundant as usual. A major problem has been the fraudulent termite operators who have taken thousands of dollars from Indiana homeowners.

Studies on Chemical Control of Insects Affecting Alfalfa Seed Production

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The farmer who desires to produce alfalfa seed in Indiana is confronted with many problems which may interfere with obtaining a successful seed yield. Foremost, are the problems of injurious insects, diseases, pollination, and the lack of alfalfa varieties inherently adapted to seed production in the State.

Numerous reports have been made by investigators on the damage that insects may do to alfalfa. Before the dawn of the era of new organic insecticides for the science of applied entomology, insects might have been the most important limiting factor in alfalfa seed production, for damage was so severe in some areas as a result of insect infestation that seed production was generally unprofitable. Today, because of these new insecticides, the insect problem need not be the one of prime importance in most cases.

Following World War II when DDT was released, investigators studied the use of this new material on alfalfa for seed production. Poos, (1945) found DDT to be effective against the potato leafhopper, *Empoasca fabae* Harris; Lieberman, (1946) and Sorenson and Carlson, (1946) found that seed yields of alfalfa could be increased in Utah by controlling plant bug species with DDT. Pederson (1948) showed that some insects only moderately controlled by DDT were controlled by BHC, and found that chlordane and toxaphene were especially effective against grasshoppers.

Wilson, (1949) initiated studies in 1948 on the use of organic insecticides to control alfalfa insects in Indiana. Since that time studies have been continued in the vicinity of Lafayette on heavy soils and in northern Indiana on sandy soils at the Purdue Sand Field in Culver. The Departments of Agronomy and Entomology at Purdue have cooperated to determine the damage caused by insects and the insect problems involved in Indiana in alfalfa seed production as well as the use of new organic insecticides for control of these insects. Information was desired not only on the toxicities and residual effects of these new materials, but also on the effects on pollination, seed yields, and insect populations not controlled by these insecticides. Wilson and Davis (1952) have reported how leafhopper and aphid populations may build up to tremendous numbers following the use of certain insecticides on alfalfa. This paper reports results obtained from five field experiments conducted during the seasons of 1949, 1950, and 1951.

Methods

Seed production studies in all experiments were made on the second alfalfa crop. The first crop was harvested for hay and the second allowed to set seed as is generally the practice. These studies were made using single prebloom insecticidal treatments which were applid when the plants were budded but not blooming. Normally, in Indiana, this is between

July 10 and 15 although it may vary depending on the management of the alfalfa.

In all experiments, randomized replicated plot designs; or where possible, to increase precision, Latin-square designs have been used. Plot sizes of 20 x 40 feet, 20 x 60 feet, 30 x 30 feet, and 30 x 40 feet have been employed. Significant differences in data were obtained with all plot sizes used.

EQUIPMENT: Materials were applied with a small experimental sprayer mounted on bicycle wheels and equipped with a 10-foot boom for legume spraying. Sprays were applied at 40 pounds pressure using CO_2 as a propellent. A speedometer was attached to the sprayer so that accurate dosages could be applied to treated plots.

INSECT SAMPLING: Insect populations were sampled one week, four weeks, and in one experiment, seven weeks after treatment with an insect sweep net; 20 sweeps being made in each plot. The sampling was always made on warm, clear days between the hours of 10 A. M. and 3 P. M.

HARVEST DATA: Harvest data consisted of both seed yields and evaluation of racemes for insect injury and pollination. Seed yields were obtained by harvesting 60 to 81 square feet in the center of each plot. To determine insect damage and pollination, twenty-five alfalfa stems picked at random were sampled in each plot. From these stems the per cent of racemes that developed and the per cent that aborted were determined and the number of racemes bearing pods as well as pods per raceme were measured to give an index of pollination.

POLLINATION: In experiments 1, 2, and 3 pollination was effected by various species of solitary bees. At the Westpoint locality this method was quite satisfactory because the experimental field was surrounded by a wooded area harboring numerous wild bees. (megachilids and andrenids).

In experiments 4 and 5 at Culver it was necessary to use honey bees since populations of the solitary bees were scarce. Honey bees show considerable promise as alfalfa pollinators and it is believed they may be successfully used in Indiana, when more is learned about bee management for seed production in this area. In 1950, when it was found that natural pollinators were not effecting pollination at Culver, bees were moved into the experimental plots after half of the bloom had withered. However, the bees pollinated the remaining bloom so that the terminal flowers of nearly all racemes produced seed pods. One and a half bushels of cleaned seed per acre were produced on the better treatments and the yield would probably have been more than doubled had the bees been placed in the field earlier.

Injurious Insects

The insect species found to be most important in alfalfa seed production were the potato leafhopper, *Empoasca fabae* (Harris), the tarnished plant bug, *Lygus oblineatus* (Say), the alfalfa plant bug, *Adelphocoris lineolatus* (Goez), the rapid plant bug, *A. rapidus* (Say), the pea aphid, *Macrosiphum pisi* (Kltb.), the grasshoppers, *Melanoplus sp.* and *Conocephalus sp.* Also present in large numbers were the adults of the meadow spittlebug, *Philaenus leucophthalmus* (L) which have not been found to be injurious to alfalfa in the adult stage.

Experimental Results

Insect data for experiments 1, 2, 3, 4, and 5 are tabulated in tables I, II, III, V, and VII. Harvest data including seed yields and individual raceme data are included in tables IV, VI, and VIII, and correlations made in experiment 5 are presented in table IX. To facilitate comparisons of insecticide toxicities, all toxicological data have been averaged and converted to a rating system and are included in table X. Examination of the tables will show the following results:

POTATO LEAFHOPPER: In five field experiments DDT has been applied at per acre dosages ranging from 0.5 to 3 pounds. Although the same treatments were not repeated in all experiments, all rates effected significant control. The residual effect of DDT as measured by the number of leafhoppers four weeks after treatment was significant for all concentrations with the exception of one experiment (table III). However, in this experiment there was a pronounced trend toward residual control at a rate of 1.75 pounds of DDT per acre.

Chlordane, aldrin, or dieldrin were non-effective or resulted in increased populations when used. However, when these materials were combined with 1 pound of DDT, 0.5 or 1 pound of chlordane, or dieldrin, control of leafhoppers with a residual effect four weeks after treatment was obtained.

Dosages of 2 to 3 pounds of toxaphene per acre were effective as residual sprays, but at the same rate there was a trend toward DDT being superior. When one pound of toxaphene was combined with one pound of DDT, control equivalent to two pounds of DDT seemed to be apparent. A dosage of 2 pounds of methoxychlor was used with residual results while two pounds of TDE effected initial control, but the residual effect was non-significant. Concentrations of 0.5 and 1 pound of Systox had residual effects. One pound of Systox was superior to 0.5 pound in initial kill, but differences were not significant four weeks later.

Initial kill was obtained with both 0.5 and 1 pound of parathion and 0.5 pound of EPN. With one exception (paration, 0.5 lb., table I) parathion and EPN had no residual effect.

Concentrations of 0.25 to 0.5 pound of lindane, 0.5 pound of gamma BHC and 0.2 pound CS-645A were non-effective.

PLANT BUGS: All three species of plant bugs previously mentioned will be considered together since materials found to be toxic to one species, likewise were toxic to the other two.

Dieldrin at rates of 0.5 and 1 pound per acre was the most effective material used against plant bugs. In one experiment (table III) when population counts were made seven weeks after treatment the 0.5 pound rate continued to effect control at the 5 per cent level of significance while the 1 pound rate of dieldrin remained significant at the one per cent level.

Results with DDT were variable. Concentrations of 1.5 pounds of DDT per acre gave high residual control of plant bug nymphs. Residual effect continued on plant bug nymphs seven weeks after treatment at a dosage of 1.75 pounds of DDT.

The adult plant bugs are more difficult to control and dosages as high as 3 pounds of DDT per acre do not always effect control (table VII).

Parathion, dieldrin, and DDT were superior to TDE and toxaphene which in turn effected higher residual control of plant bug nymphs than methoxychlor and chlordane. Except for one case against nymphal populations (table I) parathion had no residual effect. Concentrations of 0.5 pound of EPN and 0.5 to 1 pound of Systox were non-effective.

Residual control was obtained with 3 pounds of toxaphene. Concentrations of 0.25 and 0.5 pound of lindane controlled plant bugs one week after treatment, but had no residual effect four weeks later.

In combination, there was a trend toward 0.5 pound of dieldrin with 1 pound of DDT being superior to either 1 pound of chlordane or 1 pound of toxaphene combined with 1 pound of DDT.

PEA APHID: In general, concentrations of 3 pounds of DDT, 1 pound of DDT in combination with .5 and 1 pound of dieldrin, 1 pound of dieldrin, and .5 to 1 pound of Systox effected residual control of the pea aphid four weeks after treatment.

High initial kill one week after treatment, but without residual effect four weeks after treatment, was obtained with a low dosage of 0.5 pound of DDT, 1 pound of DDT in combination with 1 pound of chlordane, 1 pound of toxaphene, or 0.5 pound dieldrin, and 0.25 pound lindane, 0.5 pound parathion, or 3 pounds of toxaphene. In general, concentrations of 0.5 pound EPN and 0.5 pound dieldrin were non-effective.

GRASSHOPPERS: Of the three years, 1949, 1950, and 1951, 1949 was the only year in which grasshopper populations large enough for study were encountered. Although data in experiment 1 show highly significant differences in treatments, the populations are too low to use as a measure. However, toxaphene, chlordane, parathion, and dieldrin do appear to have effected better grasshopper control than other materials studied.

In experiment 2 (table II) where grasshopper populations were higher, toxaphene at the rate of 2 pounds; chlordane, one pound; or aldrin at one-half pound controlled grasshoppers.

MEADOW SPITTLEBUG: Spittlebug adults have not been found to damage alfalfa even though populations may be very high. Initial control without residual effect was obtained with per acre dosages of 1.5 pounds of DDT, 2 pounds of methoxychlor, 2 pounds of toxaphene, 0.5 pound of BHC, 0.25 pound of lindane, 0.5 pound of dieldrin, and 0.5 pound of parathion.

In only one experiment (table VII) were residual effects of insecticides against adult spittlebugs evident. Residual effects persisted four weeks after treatment with per acre dosages of 1 pound of dieldrin, 2 to 3 pounds of DDT, or combinations of 1 pound of DDT with 1 pound of toxaphene or 1 pound of dieldrin.

HARVEST DATA: Data for experiments 1 and 2 on seed yields are not included. Although significant differences were found in these experiments, there was considrable variability due to harvesting problems encountered. Much seed was lost due to unfavorable weather and the presence of black stem disease, *Ascochyta imperfecta.*

The effect of insect control in seed production can be noted by studying the tables for experiments 3, 4, and 5. All treatments effecting insect control increased seed yields. In experiment 3, seed yields were increased from 0.4 bushel to 1.5 bushels of cleaned seed; in experiment 4, from 0.4 bushel to 1.75 bushels; and in experiment 5, from 0.4 to 1.5 bushels. Highest yields have been obtained with treatments of 1.75 to 3 pounds of DDT per acre or a combination of 1 pound of DDT and 0.5 to 1 pound of dieldrin.

Harvest data also included sampling each plot to determine injury to racemes due to insects and the amount of pollination effected as evidenced by racemes producing pods and the total pods produced. The percentage of racemes aborted may seem high on the better treatments. This is partially due to the severity of the rating. Even though a raceme might bear pods of seed, if there was any indication that any portion of that raceme had been injured, it was placed in the aborted column, since a perfect treatment was desired.

CORRELATION OF DATA: Alfalfa seed yields were largely conditioned by the per cent of aborted racemes produced. In experiment 3, the treatment correlation between seed yields and aborted racemes was —0.853; in experiment 4, it was —0.787. The per cent of racemes aborted may be influenced by either plant bugs or leafhoppers depending on the populations. In experiment 1, a highly significant treatment correlation of 0.93 and in experiment 2, of 0.96 between per cent aborted racemes and the number of plant bug nymphs was obtained. There was no correlation between the number of leafhoppers and per cent aborted racemes. However, in experiment 5 where plant bugs were scarce a positive correlation of .952 between leafhoppers and the per cent of aborted racemes was obtained.

A considerable number of correlations were made in experiment 5, and can be studied in table IX.

Correlations were obtained as follows:

1. Seed yield correlated positively with the number of pods per 100 racemes and with the number of honey bees present.

2. Seed yield correlated negatively with leafhoppers and spittlebugs.

3. The per cent of racemes aborted correlated positively with leafhoppers and negatively with seed yields and honey bees. This latter correlation suggests that honey bees were attracted to the plots having the least number of aborted racemes or the best flowers resulting in increased seed yields or a positive correlation between seed yield and honey bees as previously mentioned.

4. There was a negative correlation between spittlebug adults and the seed yield. However, partial correlations for insects and aborted racemes were made. A significant partial correlation independent of the effects of other insects was obtained with leafhoppers and per cent aborted racemes, but when the per cent aborted racemes was compared with spittlebugs independent of the effects of leafhoppers and plant bugs the correlation was not significant. This indicated that the spittlebugs were present, but the leafhoppers were doing the damage.

TABLE I

Experiment 1. Westpoint, Indiana, 1949—Effect of Insecticides Applied to Alfalfa.

Treatment	Insects Per Twenty Sweeps								
	Leafhoppers		Plant Bug Adults		Plant Bug Nymphs		Spittle Bugs		Grasshoppers
	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.
Untreated	40.8	85.5	17.6	28.3	0	95.6	28.3	31.5	9.3
DDT, 2 lb./acre (emulsion)	4.3	30.5	11.6	21.6	0	4.2	18.3	22.1	3.5
DDT, 2 lb./acre (wettable powder)	4.3	25.8	12.3	17.1	0	9.2	19.5	19.0	4.5
DDT, 1 lb. combined with chlordane, .5 lb./acre	7.3	53.6	14.8	23.8	0	12.0	22.1	32.6	2.5
Chlordane, 1 lb./acre	31.2	130.0	16.1	21.0	0	51.8	23.5	26.1	1.3
Methoxychlor, 2 lb./acre	3.3	41.0	16.5	23.8	0	47.2	15.3	28.7	2.1
TDE, 2 lb./acre	8.3	56.3	14.8	19.6	0	22.7	23.0	31.8	4.1
Dieldrin, .5 lb./acre	42.8	131.6	7.1	21.1	0	8.2	15.5	29.3	0.8
Toxaphene, 2 lb./acre	7.2	37.5	13.0	21.8	0	22.7	13.6	19.8	0.0
Parathion, .5 lb./acre (wettable powder)	3.8	29.0	9.1	34.5	0	1.5	16.5	23.3	1.0
Least significant difference									
(5% level)	14.1	35.4	n.s.	n.s.		12.3	8.3	n.s.	3.8
(1% level)	18.8	47.3	n.s.	n.s.		16.4	11.1	n.s.	5.1

n.s.—differences non-significant statistically

TABLE II

Experiment 2. Rossville, Indiana, 1949—Effect of Insecticides Applied to Alfalfa.

Treatment	Insects Per Twenty Sweeps									
	Leafhoppers		Plant Bug Adults		Plant Bug Nymphs		Spittle Bugs		Grasshoppers	
	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.
Untreated	61.4	107.8	74	23.8	0	62.3	38.9	20.4	34.3	9.1
DDT, 2 lb./acre	4.0	6.8	55	25.8	0	10.4	8.3	9.9	23.3	9.2
DDT, 1 lb., and chlordane, 1 lb./acre	7.8	10.4	47	26.3	0	19.0	19.8	10.0	13.3	7.7
Toxaphene, 2 lb./acre	16.0	8.9	49	26.9	0	21.9	14.0	10.3	6.3	8.0
Aldrin, .5 lb./acre	144.0	253.1	56	21.5	0	28.5	39.8	15.0	11.6	3.5
Chlordane, 1 lb./acre	93.0	78.0	63	22.9	0	40.0	39.4	17.5	11.6	4.3
BHC, .5 lb. gamma/acre	62.8	76.9	50	22.9	0	17.9	12.1	7.1	26.3	9.5
CS-645A, .2 lb./acre	32.9	34.8	54	19.4	0	42.6	38.3	15.1	26.1	8.8
Least significant difference										
(5% level)	51.6	81.4	n.s.	n.s.		14.2	14.5	n.s.	13.0	n.s.
(1% level)	68.9	108.8	n.s.	n.s.		19.0	19.4	n.s.	17.4	n.s.

n.s.—differences non-significant statistically

TABLE III

Experiment 3. Westpoint, Indiana, 1950—Effect of Insecticides Applied to Alfalfa.

Treatment	Insects Per Twenty Sweeps						
	Leafhoppers		Plant Bug Adults		Plant Bug Nymphs		Aphids
	1 wk.	4 wks.	4 wks.	7 wks.	4 wks.	7 wks,	1 wk.
Untreated	25.8	62.0	29.2	37.3	17.2	31.3	73.8
DDT, .5 lb./acre	6.2	61.8	11.8	27.3	3.2	25.3	9.4
DDT, 1 lb./acre	11.8	50.2	23.6	47.3	4.4	28.6	10.8
DDT, 1.75 lb./acre	2.6	34.4	25.4	29.3	1.6	5.3	9.4
DDT, 1 lb. and chlordane, 1 lb./acre	9.8	44.2	26.6	24.0	5.4	30.6	10.0
DDT, 1 lb. and toxaphene, 1 lb./acre	7.6	40.2	30.6	30.0	6.2	18.6	7.4
DDT, 1 lb. and dieldrin, .5 lb./acre	4.4	48.0	19.6	20.7	1.8	10.0	10.2
Dieldrin, .5 lb/acre	25.2	84.2	9.6	13.3	0.6	10.0	54.8
Dieldrin, 1 lb./acre	33.6	75.6	4.6	8.0	0.4	1.3	28.0
Least signicant difference							
(5% level)	11.4	n.s.	n.s.	20.5	6.4	16.0	28.1
(1% level)	15.4	n.s.	n.s.	29.8	8.6	23.4	37.8

n.s.—non-significant statistically

TABLE IV

Experiment 3. Westpoint, Indiana, 1950 (companion table to table 3)
The Effect of Insect Control on Alfalfa Seed Production

Treatment	Raceme Data			Seed Yield	
	Percent Aborted	Racemes With Pods Per Stem	Total Pods Per Stem	Grams Per 60 Sq. Ft.	Pounds Per Acre
Untreated	87.8	12.5	30.8	15.6	25
DDT, .5 lb./acre	71.8	21.7	69.7	28.7	46
DDT, 1 lb./acre	73.7	17.2	50.2	18.7	30
DDT, 1.75 lb./acre	65.1	21.3	78.1	50.3	80
DDT, 1 lb., chlordane, 1 lb./acre	75.7	19.5	72.9	31.7	51
DDT, 1 lb./acre toxaphene, 1 lb./acre	62.8	18.4	63.1	35.9	57
DDT, 1 lb./acre dieldrin, .5 lb./acre	50.7	19.4	72.1	58.1	93
Dieldrin, .5 lb./acre	84.9	17.0	52.5	30.5	49
Dieldrin, 1 lb./acre	75.9	21.6	65.2	33.7	54
Least significant difference (5% level)	9.6	4.9	26.3	25.0	
(1% level)	13.2	n.s.	n.s.	n.s.	

n.s.—non-significant statistically

TABLE V
Experiment 4. Purdue Sand Field, Culver, Indiana—1950
Effect of Insecticides Applied to Alfalfa

Treatment	Insects Per Twenty Sweeps						
	Leafhoppers		Total Plant Bugs		Aphids		Spittle Bugs
	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.
Untreated	45.4	189.3	28.0	16.6	115.8	53.3	95.0
DDT, 3 lb./acre	7.8	42.6	9.6	4.6	5.8	9.3	36.2
DDT, 1.5 lb./acre	8.4	51.3	10.8	8.0	5.2	37.3	50.4
Toxaphene, 3 lb./acre	19.6	107.3	14.4	4.6	32.2	329.6	40.0
Lindane, .25 lb./acre	32.6	263.3	12.8	10.0	19.8	152.6	44.4
Lindane, .5 lb./acre	35.4	379.3	8.8	21.3	4.0	42.6	29.6
Dieldrin, .5 lb./acre	38.6	517.3	9.8	8.0	132.8	302.0	44.6
EPN, .5 lb./acre	23.6	261.3	25.4	29.3	80.8	163.3	75.8
Parathion, .5 lb./acre	10.4	128.0	13.8	24.6	2.6	50.0	53.0
Parathion, 1 lb./acre	10.8	134.0	14.2	19.3	4.6	16.6	56.4
Least significant difference (5% level)	19.2	135.1	9.9	12.1	54.8	185.2	29.1
(1% level)	25.8	185.0	13.4	16.6	73.6	253.7	39.0

TABLE VI

Experiment 4. Purdue Sand Farm, Culver, Indiana, 1950 (companion table to table 5)
The Effect of Insect Control on Alfalfa Seed Production

Treatment	Raceme Data			Seed Yield	
	Percent Aborted	Racemes With Pods Per Stem	Total Pods Per Stem	Grams Per 60 Sq. Ft.	Pounds Per Acre
Untreated	91.5	4.3	10.5	19.8	32
DDT, 3 lb./acre	64.8	5.3	18.5	67.8	108
DDT, 1.5 lb./acre	63.0	5.7	18.0	52.8	84
Toxaphane 3 lb./acre	82.1	5.0	14.3	18.1	29
Lindane 0.25 lb./acre	89.4	3.9	9.8	25.2	40
Lindane 0.5 lb./acre	85.0	3.8	1.1	26.5	42
Dieldrin 0.5 lb./acre	75.7	6.3	19.8	50.9	81
EPN 0.5 lb./acre	90.6	3.9	10.0	10.6	17
Parathion 0.5 lb./acre	73.6	4.6	15.9	41.0	66
Parathion 1 lb./acre	74.5	5.0	15.3	29.3	47
Least significant difference (5% level)	10.0	n.s.	6.3	17.2	
(1%level)	13.8	n.s.	n.s.	23.5	

n.s.—difference—statistically non-significant

TABLE VII

Experiment 5. Purdue Sand Field, Culver, Indiana, 1951
Effect of Insecticides Applied to Alfalfa

Treatment	Insects Per Twenty Sweeps							
	Leafhoppers		Plant Bugs		Aphids		Spittle Bugs	
	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.	1 wk.	4 wks.
Untreated	88	109	9.2	6.0	65	123	252	158
DDT, 3 lb./acre	6	7	10.8	7.2	4	10	158	97
DDT, 2 lb./acre	15	10	6.8	6.8	48	9	217	111
DDT, 1 lb./acre and toxaphene, 1 lb./acre	26	18	8.8	7.6	50	22	190	97
DDT, 1 lb./acre and dieldrin, 1 lb./acre	20	18	2.0	4.0	6	5	124	88
DDT, 1 lb./acre and dieldrin, .5 lb./acre	22	15	4.8	10.8	0	10	196	98
Dieldrin, 1 lb./acre	120	153	1.2	6.0	14	34	139	111
Systox, 1 lb./acre	18	22	4.8	6.4	10	2	224	142
Systox, .5 lb./acre	41	42	7.2	9.6	4	4	258	122
Least significant difference (5% level)	23	49	6.1	n.s.	18	27	63	37
(1% level)	31	65	8.2	n.s.	24	36	84	50

n.s.—differences non-significant statistically

TABLE VIII

Experiment 5. Purdue Sand Farm, Culver, Indiana, 1951 (companion to table 7) The Effect of Controlling Injurious Insects of Alfalfa on Honey Bees and Seed Production.

Treatment	Honey Bees Per 20 Sweeps Full Bloom	Raceme Data		Seed Yields	
		Percent Aborted	Rods Per 100 Racemes With Pods	Grams Per 81 Sq. Ft.	Pounds Per Acre
Untreated	9.6	67	237	21.5	25
DDT, 3 lbs./acre	19.2	33	255	45.2	54
DDT, 2 lbs./acre	13.6	31	267	52.0	62
DDT, 1 lb., toxaphene, 1 lb./acre	11.2	33	258	41.4	49
DDT, 1 lb., dieldrin, .5 lb./acre	16.0	35	276	45.1	53
DDT, 1 lb., dieldrin, 1 lb./acre	16.0	34	305	58.0	69
Dieldrin, 1 lb./acre	7.2	66	244	30.5	36
Systox, 1 lb./acre	14.0	40	246	35.7	42
Systox, .5 lb./acre	8.8	49	257	27.4	32
Least signficant difference (5% level)	6.9	13	38	16.7	
(1% level)	n.s.	18	51	20.9	

n.s.—non-significant statistically

TABLE IX

Experiment 5. Purdue Sand Field, Culver, Indiana, 1951 Correlation Coefficients Associated With Seed Yield, Damage, Injurious Insects, and Honey Bees

	Seed Yield	Pods Per 100 Racemes With Pods	Percent Racemes Aborted	Leaf-hoppers	Spittle bugs	Plant Bugs	Honey Bees
Seed Yield	xxx	.839**	—.832**	—.684*	—.769*	—.191	.728*
Pods Per 100 Racemes With Pods	+.839**	xxx	—.618	......	......	......	.512
Percent Racemes Aborted	—.832**	—.618	xxx	.952**	.632	—.169	—.760*
Leafhoppers	—.684*	......	.952**	xxx	—.639	—.045	......
Spittlebugs	—.769*	......	.632	—.639	xxx	—.085	......
Plant Bugs	—.191	......	—.169	—.045	—.085	xxx	......
Honey Bees	.728*	.512	—.760*	......	......	......	xxx

* Statistically Significant
** Statistically Highly Significant

TABLE X

Summary of Toxic Action of Various Treatments on Insect Populations on Alfalfa; Data of All Experiments Averaged and Converted to Numerical Ratings from 1-9.

Key to Ratings

1—very high toxicity
2—high toxicity
3—fair toxicity
4—above average toxicity
5—average toxicity
6—below average toxicity
7—little toxicity
8—very little toxicity
9—no toxicity

Insecticide—Pounds Per Acre	Leafhoppers		Plant Bugs	Aphids		Grasshoppers
	Initial Kill	Residual Effect	Residual Effect	Initial Kill	Residual Effect	Initial Kill
Aldrin 0.5	9	9*	4	—	—	2
BHC 0.5 gamma	9	9	2	—	—	7
Chlordane 1.0	8	9*	5.5	—	—	2
DDT 0.5	2	9	3	1	—	—
DDT 1.0	2	6	3	1	—	—
DDT 1.5	1	1.5	3	1	6	—
DDT 1.75	1	1	1.5	1	—	—
DDT 2.0	1	1	1.2	—	—	5
DDT 2.0 (wettable powder)	1	1	1.5	—	—	5
DDT 3.0	1	1	1	1	1	—
DDT 1.0 & toxaphene 1.0	3	2.5	4	1	—	—
DDT 1.0 & dieldrin 1.0	2.5	2.0	1.5	—	—	—
DDT 1.0 & dieldrin 0.5	2.2	3.3	—	1	—	—
DDT 1.0 & chlordane 1.0	2.3	2.7	3	1	—	—
DDT 1.0 & chlordane 0.5	2.0	5.0	2	—	—	3
Dieldrin 0.5	9	9*	3	8	9*	1
Dieldrin 1.0	9	9*	1	4	—	—
EPN 0.5	4	9*	9*	6.5	9*	—

TABLE X (Continued)

1—very high toxicity
2—high toxicity
3—fair toxicity
4—above average toxicity
5—average toxicity
6—below average toxicity
7—little toxicity
8—very little toxicity
9—no toxicity

Insecticide—Pounds Per Acre	Leafhoppers		Plant Bugs	Aphids		Grasshoppers
	Initial Kill	Residual Effect	Residual Effect	Initial Kill	Residual Effect	Initial Kill
Lindane 0.25	6	9*	5	3	9*	—
Lindane 0.5	6	9*	9*	1	7	—
Methoxychlor 2.0	1	3	5	—	—	3
Parathion 0.5	2	6	9	1	9	2
Parathion 1.0	1.5	6	9	1	2	—
Systox 0.5	5	4	—	—	—	—
Systox 1.0	2	2	—	—	—	—
TDE 2.0	2	5	3	—	—	5
Toxaphene 3.0	3	4.5	1	4	9*	—
Toxaphene 2.0	3	4.5	3	—	—	—

* Insect populations tend to build up higher than untreated
— No information

Summary and Conclusions

Studies over a period of five seasons (one of which was reported in 1949 and three of which are reported in this paper) show that insect control is one of the most important factors in alfalfa seed production. A single pre-bloom spray has increased seed yields from 0.4 to 1.75 bushels of cleaned seed per acre. This was done by controlling the potato leafhopper, *Empoasca fabae* (Harris) and three species of plant bugs: *Lygus oblineatus* (Say), *Adelphocoris lineolatus* (Goez), and *A. rapidus* (Say). Research in progress to be reported at a later date suggests that considerable damage is effected by insects before the prebloom spray is applied and that a complete insect control program may include as many as three treatments applied early, prebloom, and in full bloom. These multiple treatments increased the yield considerably over the single prebloom treatment.

If only one spray is to be applied during the season, a long residual spray is required. For this purpose a per acre dosage of a-combination of 1 pound of DDT and 0.5 to 1 pound of dieldrin, or 2 to 3 pounds of DDT alone have given the best results.

Although a yield of 1.75 bushels of cleaned alfalfa seed may seem low, this amount would be profitable to Indiana farmers at the present high cost of seed. Newer selections being studied show promise of being heavy seed producers and it is believed that when selections are ready for release alfalfa seed yields can be increased greatly in the State.

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Additional Notes on Indiana Psocoptera

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Since publication of my paper on Indiana psocids (1950), seven species have been added to the State list, raising the total to 64. Also several other records of interest have been obtained. Names preceded by an asterisk are those of species new to the State.

FAMILY LEPIDOPSOCIDAE

**Lepolepsis occidentalis* Mockford

Indiana records of this species are listed with the description (Mockford, in press).

FAMILY TROCTIDEA (=Liposcelidae)

Embidopsocus needhami (Enderlein)

Two males of this species were taken together with females at Bloomington, June 24, 1951, under loose bark of dead pines. These males are wingless and are much smaller and paler than the females. They measure 1.20 and 1.26 mm. in body length respectively, while accompanying females vary from 1.88 to 2.10 mm.

FAMILY PSOCATROPIDAE

Psyllipsocus ramburii Selys-Longchamps

A macropterous specimen of this insect was taken in a cellar at Indianapolis, July 20, 1945.

FAMILY CAECILIIDAE

**Caecilius manterae* Sommerman

This species was first taken in Indiana at Bacon's Swamp, Indianapolis, September 7, 1951, where I found a female and six nymphs in a clump of dry cattails.

**Caecilius posticus* Banks

Specimens have been taken at two Indiana localities: Bloomington VII/4/51 (ground litter in Sassareas grove) macropterous ♀; Dunes State Park IX/6/52 (ground litter in Oak woods on dune) 5♂, 3 micropterous ♀, 2N.

**Caecilius sommermanae* Mockford

This species was not distinguished in my first paper from *C. aurantiacus*. Indiana records are listed with the description (Mockford, in press).

FAMILY PERIPSOCIDAE

Ectopsocus californicus (Banks)

Sixteen *E. californicus* females were taken in dry leaves at Bloomington, July 11, 1951. Prior to this record only two specimens had been collected in the State.

FAMILY PHILOTARSIDAE

Aaroniella maculosa (Aaron)

This insect has been found at a second Indiana locality: Eagle Crest Forest Preserve (Marion Co.) VII/31/52 (on bark of Oak trunk) ♂, 17♀.

FAMILY MESOPSOCIDAE

Mesopsocus sp. nr. *unipunctatus*

This is the species listed in my first paper as *Mesopsocus? immunis* (Stephens). The question mark was misplaced and should have followed the specific name. The species has subsequently been redetermined to be a form near *unipunctatus.*

FAMILY ELIPSOCIDAE

**Reuterella* sp.

Numerous nymphs of this psocid were found on the trunk of a large beech tree in a solution valley at Turkey Run State Park, September 14 and 15, 1951. They inhabited small, dense webs spun on open bark or in heavy lichens. I returned to the spot a week later hoping to find adults, but still only nymphs could be found. Several of these were reared, and six adults were obtained (2♂, 4♀), the first of which matured on October 15. The species is close to the European *R. helvimacula* End., but it has not yet been possible to obtain specimens of the latter for comparison. Dr. Sommerman writes *(in litt.)* that she has taken specimens of a *Reuterella* at an Illinois locality. I am aware of no previous published records of this genus from North America.

FAMILY PSOCIDAE

Psocus floridanus Banks

The second Indiana record is from the same locality as the first: Dunes State Park IX/5/52 (Oak trunks on 2nd dunal ridge from Lake Michigan) 3♂, 2♀.

Psocus lichenatus Walsh

The second specimen from Indiana is from the same locality as the first: Turkey Run State Park IX/14/51 (trunk of large Maple) ♀.

**Trichadenotecnum slossonae* (Banks)

A single male was taken on a Red Maple trunk in a low woods at Dunes State Park, September 6, 1952.

**Trichadenotecnum unum* Sommerman

A single dead female was beaten from a Hemlock at Turkey Run State Park, September 14, 1951.

Blastopsocus variabilis (Aaron)

This species has been taken at several additional Indiana localities: Dunes State Park VII/15/50 (Cottonwood trunk) ♀; Yellowwood Lake X/15/50 ♀; Marion Co., south county line rd. one mi. west of State Hgwy. 135 IX/8/51 (dead branches in woodlot) ♂.

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Notes and Records of Indiana Odonata, 1951-1952

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Records of 834 specimens of Odonata taken in Indiana during 1951 and 1952, or collected earlier but not studied until this time, have been tabulated. These records furnish a considerable addition to our knowledge of the dragonfly fauna of the state. Sixty-eight species, two of which were previously unknown from Indiana, are represented in the collections. These two additions bring the state list of Odonata to 146 species.

Records of rare species, new or interesting observations of other species and counties in which a species was found for the first time are included in the following list. The numbers of Williamson's 1917 list (3) and later interpolations in the author's "Records of Indiana Dragonflies" (1) and more recent "Notes" (2) are used. The species new to the state list are starred (*).

3. *Calopteryx maculatum* (Beauvais). Clinton, Howard.

4. *Hetaerina americana* (Fabricius). Clark.

5. *H. titia* (Drury). Elkhart.

5a. *Archilestes grandis* (Rambur). This species was first found east of the Mississippi River at Oxford, Ohio, in 1927, by the late E. B. Williamson (4). It has since been taken in several central and eastern states, until its range is known to extend, at least, to Pennsylvania and North Carolina. The only previous record for Indiana is based on a single specimen taken along Hannah Creek, near Liberty, in Union County, October 6, 1940. Extensive search at this locality on September 13, 1952, yielded no evidence of this species and few other dragonflies (a male of *C. maculatum*, and one female each of *Argia violacea* and *Enallagma civile*) along the creek, although individuals of *Anax junius* were rather abundant in the tall vegetation bordering the wooded creek banks. There was no flow of water in the creek at that time, but there were occasional pools in the creek bed which is rock-bottomed, and from 10 to 40 feet wide. However, a colony of *A. grandis* was discovered along a tributary of the creek. This streamlet has a rock bottom, is two to four feet wide and there was a flow of water of slight depth. A total of 19 males and two females, including one mating pair, were taken along the small stream within 100 yards of its confluence with Hannah Creek.

11. *Lestes rectangularis* Say. Clinton, Fulton.

15. *Argia apicalis* (Say). Howard.

20. *A. violacea* (Hagen). Scott.

21. *Enallagma antennatum* (Say). Scott.

22a. *E. basidens* Calvert. Tippecanoe.

24. *E. carunculatum* Morse. Fulton.

25. *E. civile* (Hagen). Fulton, Union.

33. *E. vesperum* Calvert. Starke.

43. *Ischnura verticalis* (Say). Scott.

52a. *Gomphus amnicola* Walsh. Tippecanoe: Wabash River, near Lafayette, August 3, 1952, 1 ♀ ; Tippecanoe River, near Hog Point bridge, July 6, 1952, 8♂6♀, July 20, 16♂9♀, August 3, 7♂3♀, August 4, 2♂3♀, none were found September 7. Most of these specimens were taken in the strip of vegetation, two to five feet high, and a few feet wide on the river bank and forming the margin along a corn field. A few were taken in similar vegetation on the slope of the bank, some 8 to 15 feet high, rising from near water level two to five rods from the river proper. The margin within this bank is rather level and is open and bare of low vegetation but shaded by trees and bushes. Four other species of Gomphidae were also taken, all in July—*G. plagiatus, G. vastus, G. ventricosus* and *Dromogomphus spinosus.* Other common Odonata, including *Calopteryx maculatum,* three species each of Argia and Enallagma, *Ischnura verticalis, Plathemis lydia,* and *Erythemis simplicicollis* were present in July and August; *Sympetrum rubicundulum* was common July 6, but was not found later. On September 7 only one specimen each of *Argia sedula, Enallagma basidens* and *Macromia illinoiensis* were taken although additional individuals of Macromia were seen.

58. *G. graslinellus* Walsh. Scott.

70. *Boyeria vinosa* (Say). Clinton.

93a. **Somatochlora hineana* Williamson. A male of this species, collected at Gary, June 22, 1945, was presented to me by the collector, William Kowlek. This species has been known previously only from the type series of seven specimens (3♂4♀), all collected along the North Fork of Little Miami River, near Indian Lake, Logan County, Ohio, in June, 1929, and July, 1930 (5).

95. *S. tenebrosa* (Say). Tippecanoe, near Wabash River: July 12, 1952, 1♀, flying over a lawn at dusk, and September 5, 1952, 1♂, "hawking" over swampy area in meadow, about 12 and 3 miles, respectively, west of West Lafayette.

*96a. **Ladona deplanata* (Rambur). Clark: Schlamm Lake, June 6, 1952, 4♂2♀; Francke Lake, June 7, 1952, 2♀. This is a southeastern species, previously known as an Atlantic Coastal form, ranging from New Jersey to Florida. Records in the literature are somewhat confused because of a question of the exact systematic relationship or distinctness of the three described species—*deplanata, exusta* (Say) and *julia* (Uhler). Numerous individuals were present at both lakes, fluttering over bare areas along the shore, and alighting on the bare ground in a manner reminiscent of *Plathemis lydia,* although less active than the latter species, and not inclined to race along the lake margin.

103. *Holotania vibrans* (Fabricius). Clark: stream course in State Forest, June 7, 1952, 2♂. Five additional specimens were taken in the Forest and presented to me by students at the Purdue University Summer Forestry Camp—July 21, 1♂; July 27, 1♂; July 29, 1♂1♀; August 1, 1♂.

107. *Erythemis simplicicollis* (Say). Starke.

110. *Sympetrum internum* Montgomery. Fulton: Lake Manitou, September 11, 1952, 1♂. The great abundance of this, previously extremely rare, species at Hadley's Lake in Tippecanoe County in 1943 and 1944 has been recorded (2). Few individuals of the genus and none of *internum* have been found at this locality since 1944 until 1952. With the discovery of the genus in fair numbers in 1952 a series of observations

and collections were made at the lake to determine the relative abundance of the different species. The results are given in the following table.

	July 20	Sept. 7	Sept. 21	Sept. 28	Oct. 12	Oct. 19
ambiguum		4♂1♀				
internum			16♂4♀	46♂1♀	1♂	
obtrusum			1♂	7♂	4♂	1♀
rubicundulum	2♂	2♂2♀	2♂	5♂		
vicinum			7♂		1♀	

No Odonata were seen on October 5, when the weather was very unfavorable—strong wind and low temperature. Other Odonata were not common at the lake, with the exception of *Ischnura verticalis, Perithemis tenera* and *Plathemis lydia* during July and September; *Enallagma civile* was abundant in September and *Aeshna constricta* was present on September 21 and 28. On October 12 the Odonata seen in addition to the six specimens of Sympetrum were a male each of *A. constricta* and *Lestes congener.* The specimen of *obtrusum* taken was the only dragonfly seen October 19. One male of *S. internum* was taken on the campus of Purdue University, September 30. Species of Sympetrum were also studied at a swampy area in a meadow near West Lafayette and about five miles distant from Hadley's Lake. On September 5, collections consisted of 2♂ of *rubicundulum* and 9♂1♀ of *semicinctum,* on September 30, 15♂ of *obtrusum* and 2♂ of *rubicundulum.*

112. *S. rubicundulum* (Say). Clinton, Fulton, Starke.
114. *S. vicinum* (Hagen). Fulton.
119. *Celithemis eponina* (Drury). Fulton.
121. *Pantala flavescens* (Fabricius). Clinton.
124. *Tramea lacerata* Hagen. Fulton.

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The Periodical Cicada *Magicicada septendecim* (L) in Indiana

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There are two races of the periodical cicada—race *septendecim*, which takes 17 years to complete its life cycle, and race *tredicim*, which takes 13 years. On the whole, the 13-year race is more southern in distribution, but the territory of the two races overlap, and both races occur in Indiana. There is no perceptible difference in the appearance of the individuals of the two races, but they have not been observed to mate when the individuals of the two races appear at the same time in the same place. The same broods of the two races will appear in the same year only once in every 221 years.

Two distinct forms of cicadas appear in both races—a large form and a small or "dwarf" one, which is about 2/3 as large as the other. The larger form is always more numerous. The small form was described as a new species, *M. cassinii*, by Fisher in 1851. The writer, for the purposes of this paper, has followed Riley (1885) in considering this small form a variety instead of a distinct species. The body of the adults of both races of the species proper is about 1⅛ inches long from the head to the tip of the abdomen, and 1½ inches long from the head to the tip of the folded wings; the body color is black, except that either the entire underside of abdomen or the edge of the segments is a dull brownish-orange, and the last four or five dorsal segments, especially in the males, are edged with orange; the eyes are red, becoming orange in color after death; and the wings are orange. The small form (var. *cassinii*) is about ⅝ inch long to the tip of abdomen and 1⅛ inches to tip of folded wings. The color is the same as that in the main species except that the underside of the abdomen is usually entirely black and the dorsal segments are never marked with orange.

Although it takes 17 years and 13 years respectively for the individuals of the two races to complete their development, swarms, or broods, of the periodical cicada appear somewhere in the United States every year. Several systems of designating these broods have been proposed, but the one that is accepted is that proposed by Marlatt in 1898. He used the Roman numerals I through XVII to designate the various broods of the 17-year race and XVIII through XXX for those of the 13-year race. The brood of the 17-year race which appeared in 1893 was numbered I and that of the 13-year race which appeared that year was numbered XVIII. Seven of the 17-year broods and two of the 13-year ones have been reported as occuring in Indiana.

Although there have been over 600 papers published about the periodical cicada in the United States, only two have been devoted exclusively to the periodical cicada in Indiana. The first of these was by A. W. Butler (1886) in which he reported his observations on the outbreak of the periodical cicada in 1885 (Brood X) in southeastern Indiana. The other paper was by F. M. Webster (1899) in which he gave the distribution of Broods X, XIII, and XIV in the state. Of the other papers which mention the periodical cicada in Indiana, the following are probably the most important. Riley (1885) listed the then known occurrence of this species in Indiana. He stated that the earliest instance of its being observed in the state was in Tippecanoe County in 1834 (Brood X). Marlatt (1907) published a splendid monograph on the species. Hyslop (1935 and 1940) gave complete distribution records of Broods X and XIV. J. J. Davis, in his series of papers "Insects of Indiana for the Year ——" which have appeared annually in the Proceedings of the Indiana Academy of Science since 1926, has noted the appearance of the various broods. Thomas Say, the father of American Entomology, makes no mention of the periodical cicada in Indiana. His one brief paper on this insect is a criticism of the use of the name "locust" for it.

The life history of the periodical cicada is well known (Marlatt, 1907). The last instar nymphs start to appear above ground in Indiana during the last half of May. They crawl up trees, fence posts, and other objects and molt. The females deposit their eggs in the twigs and small limbs of trees and shrubs, causing serious damage as the twigs and limbs die beyond the point of oviposition. The adults live for about three weeks and most of them have disappeared by the first part of July. The eggs hatch in about seven weeks. The nymphs emerge and drop to the ground where they dig in and construct cells along the roots in which they spend the rest of their nymphal lives.

The Broods of the Periodical Cicada Occurring in Indiana

Seven broods (I, II, VI, X, XII, XIII and XIV) of race *septendecim* have been reported as occurring in Indiana. Three of these (I, II, and XII) are represented only by isolated outposts of the main body of the brood.

Brood I (1944-1961[1]).—This brood is a minor one. Its center of abundance being in eastern Pennsylvania, Maryland, Virginia and West Virginia.

Reported by Riley (1885, 1893) as occurring in Sullivan (1842, 1859), Knox (1842, 1859), and Posey (1859) counties. Riley obtained these records by personal correspondence and from the unpublished manuscript of Dr. Gideon Smith, an early student of the periodical cicada. No reports of this brood were obtained from Indiana in 1876, 1893, 1910, 1927, or 1944.

Brood II (1945-1962).—This is a major brood, the main body of which occurs along the Atlantic seaboard to the east and south of Brood I.

Recorded from Dearborn County (1843, 1860) and from Posey (1877) by Riley in 1885. From Dearborn County in 1894 by Marlatt (1907), and from Fountain County in 1911 (Insect Pest Survey Bulletin 8). The Fountain County report is open to question as Brood XXIII of the 13-year race also appeared in Indiana in 1911. There are no records of the appearance of this brood in Indiana in 1928 and 1945.

Brood VI (1949-1966).—This is a widespread, sparsely populated brood ranging from South Carolina and Georgia north to northern New York and Wisconsin.

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[1] Numbers in parentheses following the brood refer to the dates of the last and next appearance of the brood.

In Indiana, this brood has been reported from 24 counties which are distributed throughout the state (Insect Pest Survey Bulletin 12). No dense swarms have been observed anywhere in the state; as a rule only a few specimens appear in each locality.

Brood X (1936-1953).—This is the largest of the 17-year broods, appearing in great swarms throughout its range which extends from Massachusetts to Georgia and west to the Mississippi river.

Dense swarms of this brood have been observed in every county of Indiana. However, it does not seem to occur in the northern half of Lake and Porter counties, and the northwest corner of LaPorte county. A. W. Butler (1886) studied the habits and natural enemies of this brood in southeastern Indiana and F. M. Webster (1899) reported on its distribution in the state. This is the brood which does so much damage to young orchards which have been planted near wooded areas.

Brood XII (1938-1955).—This is a small, sparsely populated brood which has been reported from a few localities in Maryland, West Virginia, Ohio, Indiana and Illinois.

In Indiana this brood was first reported from Allen County in 1887 (Marlatt, 1907) and was not reported again until 1938 when Professor Davis (Insect Pest Survey Bulletin 18) reported it from Orange County.

Brood XIII (1939-1956).—This is an abundant, compact brood occurring in eastern Iowa, southern Wisconsin, northern Illinois, northwestern Indiana and southern Michigan.

In Indiana this brood occurs only near the lake shore in Lake, Porter and LaPorte counties, occupying the territory just north of that occupied by Brood X (Webster, 1899).

Brood XIV (1940-1957).—This is a large brood which extends from Massachusetts to North Carolina and west to the Mississippi river. It is the brood which was observed by the Pilgrims in 1634.

It occurs throughout Indiana, but is more common from Tippecanoe County south. It has been recorded from 40 counties (Hyslop, 1940). It has not been observed in dense swarms except in Brown and Warrick counties.

Two broods (XIX and XXIII) of the race *tredecim* occur in Indiana.

Brood XIX (1946-1959).—This is the largest of the 13-year broods, occurring in the southern states and in the Mississippi valley north to southern Iowa and up the Ohio and Wabash valleys to western Indiana.

It does not appear in great numbers, but has been reported from eight counties in the western part of the state from Posey and Warrick on the south to Newton and Jasper on the north (Insect Pest Survey Bull. 13).

Brood XXIII (1950-1963).—This is the second largest brood of 13-year cicadas, occupying the Mississippi and Ohio valleys into northern Illinois and Indiana.

This brood reaches much farther north in Indiana than does the other 13-year brood. It has been recorded as occurring in 18 counties by Marlatt (1907), and the writer has seen specimens from three additional counties. It is much more abundant in southwestern Indiana where it did much damage to fruit trees in 1950. The known northern limits in the state are Fountain, Tippecanoe and Fayette counties.

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A Preliminary Report on Biometrical Studies on *Tropisternus striolatus* (LeConte) and *T. mexicanus* (Castelnau) (Coleoptera: Hydrophilidae)[1,2]

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The genus *Tropisternus* is widely distributed in North and South America. Eight species have been described from the United States east of the Mississippi River. Of these only *T. striolatus* belongs to *Tropisternus s. str., i.e.* the typical subgenus with the prosternal process open in front. Hatch (1930) recorded *T. mexicanus* (Castelnau) from Oklahoma. Twenty-one other such specimens which resemble *T. mexicanus* in color pattern have been borrowed from various museums. The occurrence of a *mexicanus*-like form along the western edge of the range of *striolatus* suggests that the latter species may be merely a geographic race of true *mexicanus* from Mexico. One group of beetles from Kansas shows both extremes as well as the intermediate condition in the width of the pronotal spot, the main character by which *mexicanus* can be separated from *striolatus*.

To test this assumption 362 beetles from various parts of the United States and Mexico were carefully measured and studied. Lots were formed by the random selection of measured specimens to represent various populations. The number of beetles in each lot varied depending upon available material. The sizes of lots ranged from 10 to 25 beetles of each sex.

Two geographic regions of the United States were represented by the lots of typical *striolatus*. The first lot included beetles from Tennessee, Ohio, Missouri and Illinois; the second specimens from southern Georgia and Florida. Another lot consisted of all specimens available from Texas, Oklahoma, Kansas, and Missouri which closely resembled typical *mexicanus*. A fourth lot was composed of specimens from Mexican collections, and presumably represents typical *mexicanus*.

After the measurements were obtained and the lots were selected, "t" values were found for each of three comparisons among the lots. The values for body measurements were used to estimate the degree of morphological similarity of the various lots. No significant values of "t" were obtained between the two lots from the Eastern United States suggesting that *T. striolatus* is a homogeneous population as far as the measurements were concerned. The values obtained when the *mexicanus*-like forms of Texas, Oklahoma, Kansas and Missouri were compared with the eastern populations were lower than when compared with typical *mexicanus*.

The *mexicanus*-like forms have pronotal spots similar to those of their Mexican neighbors, intermediate in width, or approaching those of the eastern forms. This, plus the geographic position suggests that they

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[1] Acknowledgement for his assistance in this study especially is due Dr. Frank N. Young; also appreciation is expressed for aid given by Drs. Breneman and O'Dell at Indiana University. Specimens used were borrowed from the Snow Museum, University of Kansas; University of Michigan Museum of Zoology; and the Illinois State Museum of Natural History.

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are an intermediate group linking *striolatus* with *mexicanus*. Other evidence to support this conclusion is indicated by the "t" scores. Looking at the comparisons (Table I), it will be observed that the lot from Texas, Oklahoma, Kansas, and Missouri shows lower "t" scores when compared with *mexicanus* than do the lots of Eastern specimens. If this line of reasoning can be extended further it appears also that the distribution of *striolatus* has been in an easterly direction, since the "t" scores for lots I and II show somewhat progressive increase over those of lot III.

In total length, *T. striolatus* is slightly larger than typical *T. mexicanus*, and between males, it was found that *striolatus* is about 0.0930 mm. broader at the apex of the pronotum and approximately 0.3348 mm. wider at the base of this structure. The sternal spine of *striolatus* is about 0.4466 mm. longer than in *mexicanus* and the length of the pronotum of the former exceeds that of the latter by nearly 0.2 mm.

An attempt was made to evaluate the extent of pigment on the dorsal surface of the beetles and the size and shape of the pronotal spot. Light and dark specimens of *striolatus* are to be found in different parts of the range of the species. The darkest individuals in the collections are from Florida while lighter forms come from areas north and west of this State. Some very light specimens were received from Ohio. These present a striking contrast with the Florida beetles. The few Indiana specimens that we have are typical of most *striolatus*, being intermediate in extent of pigmentation. Western specimens show the metallic green lines on the wingcases much more distinctly than do beetles in the eastern part of the range. In the former the lines and the interstices are well-defined. The color pattern of the Mexican specimens is similar to but more reduced than than of *striolatus* in the western part of its range.

The greatest variation to be found is in the size and shape of the dark pronotal spot. Dark-colored specimens have a large part of the pronotum covered by the spot. (Such specimens also show much more green in proportion to the background color of yellowish-brown on the wing-cases). In certain Florida beetles the entire pronotum may be dark green except for a thin margin of yellowish-brown.

In typical *striolatus* the pronotal spot of light-colored forms is not as extensive as in the Florida specimens. In these the spot may bear lateral extensions or "wings," or as is found in some western specimens, the pattern may be oblong and quite narrow. The latter shape is similar to that found in *mexicanus*, but in *mexicanus* the spot may be reduced to a fine, longitudinal streak isolated in the middle of the pronotum.

The most significant values of "t" are associated with the comparisons of the size of the pronotal spot. Cursory inspection of the various lots of the two species would readily lead one to expect this before measurements were made. The "t" scores (Table II) show that the difference in size of the pronotal spots of the samples varies according to the geographic location of the populations. The size of the spot, therefore, varies least between the Georgia-Florida and the Tennessee-Ohio-Missouri-Illinois groups. It varies most between specimens of Georgia and Florida and those of Texas, Oklahoma, Kansas and Missouri. Within these extremes lie the differences between the eastern and western forms of *striolatus*.

TABLE I. "t" scores obtained by comparing random selected lots of both sexes of *T. striolatus* and *T. mexicanus* on the basis of six arbitrarily chosen structural measurements.

	Males						Females					
	1	2	3	4	5	6	1	2	3	4	5	6
I x II	0.070	0.015	0.068	0.358	0.031	0.020	0.097	0.037	0.051	0.389	0.029	0.073
I x III	1.041	0.190	0.079	1.581	0.000	0.380	0.563	0.554	0.489	0.644	0.973	0.983
II x III	0.566	0.083	0.350	2.213	0.548	0.645	1.415	0.100	0.450	1.230	0.212	0.000
I x IV	4.953	6.737	6.945	14.630	7.270	5.070	5.974	7.258	8.209	11.952	6.514	6.865
II x IV	2.583	5.480	5.852	8.779	6.723	4.827	4.312	7.262	9.189	7.022	9.462	6.955
III x IV	2.635	4.404	4.748	7.523	4.265	3.194	4.068	4.658	5.900	3.245	4.208	4.213

	Lot size (n):	
Geographic region represented by each lot:	Males	Females
I Tennessee, Ohio Missouri and Illinois	25	25
II Georgia and Florida	25	25
III Texas, Oklahoma, Kansas and Missouri	11	10
IV Mexico	16	21

Structures Measured:

1 Width of the pronotum at the apex
2 Width of the pronotum at the base
3 Length of the sternal spine
4 Greatest width of the sternal spine
5 Length of the pronotum at the mid-line
6 Length of the scutellum.

TABLE II. "t" scores obtained after comparing random selected lots of *T. striolatus* and *T. mexicanus* on the basis of size of the pronotal spot.

	Males		Females	
	1	2	1	2
I x II	0.161	0.555	0.043	0.598
I x III	2.119	6.437	1.995	0.725
II x III	4.178	8.266	3.544	14.365
I x IV	6.259	38.821	8.045	26.574
II x IV	7.322	27.330	9.542	29.825
III x IV	3.363	10.021	4.149	2.985

(See Table I for the geographic regions represented by each lot and for the size of each lot.)

1—Length of the pronotal spot at the mid-line.

2—Greatest width of the pronotal spot.

In comparing male specimens it was found that the average length of the pigmented area of the pronotum in *striolatus* exceeded that of the *mexicanus* sample by .44 mm. The width of this area in the former species was found to average 2.36 mm. greater than in *mexicanus*.

At present, no adequate explanation for the color differences can be offered. It is believed that they may be due to local influences of environment or to minor gene effects.

I believe that these preliminary investigations permit the following conclusions:

1) It is highly probable that *T. striolatus* is a geographic or allopatric subspecies of *T. mexicanus*.

2) *T. striolatus* in the Eastern United States is a homogeneous population, although regionally it shows much variation in depth of color and in the size and shape of the pronotal spot.

3) Specimens from the western edge of the range of *striolatus*, so-called *mexicanus*, are probably intermediate forms linking the two species.

It now appears that all of the populations involved in this study are related and that *striolatus* very probably evolved from *mexicanus*. Further analysis of biometrical and genetic characters will be necessary to establish the exact relationships.

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Some Laboratory Experiments on Resistance of the Pomace Fly to DDT Poisoning

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Introduction

During 1951 the author carried out two experiments on resistance to DDT poisoning in the pomace fly, *Drosophila melanogaster* Meigen. One experiment was on the development of several strains of flies under p,p'-DDT treatments applied in several generations; and the principal objective was the production of a more-than-normally resistant strain and a more-than-normally susceptible strain. In the second experiment certain possible effects produced within one generation by p,p'-DDT treatments were investigated.

Both experiments were originally regarded as preliminary or exploratory in nature; but, as the author now plans to go no further with this line of work, the present report is made in the hope that others may find the methods or results suggestive.

The Basic Stock of Flies

Eight laboratory strains of pomace flies representing different geographical origins were combined in three series of mass matings (five of each sex of each strain per mating) to produce the basic strain which was designated the X strain.

Culture Methods

The flies were reared in four ounce bottles stoppered with cotton plugs. The medium contained the following ingredients, in the amounts indicated, per liter, made up to volume with water: Molasses, 135 ml.; cornmeal, 100 to 120 gms.; agar, 15 to 20 gms.; and a mold inhibitor (methyl parahydroxybenzoate), 1.5 to 2.0 gms. The prepared culture bottles were autoclaved. Yeast was added before the cultures were used; and, in addition, fresh yeast was added from time to time to provide at all times an obvious excess of food. The intention was to eliminate competition for food.

All fly strains were maintained in duplicate culture.

Temperature and Relative Humidity

The cultures were stored during their developmental periods in an incubator at 26±2°C.; but all the handling and testing of the adult flies had to be done at room temperature and room humidity, both of which varied widely. Statistically significant results were obtained in many cases in spite of large inter-replication differences which are believed to have been due largely to variations in temperature and relative humidity. The author is convinced, however, that control of both temperature and humidity are necessary if closely reproducible results are to be obtained with pomace flies in work of this sort. This conviction agrees with statements made by Weiner and Crow in 1951 (2).

Apparata Devised for Handling Flies

Three improvised apparata greatly facilitated the rapid handling of rather large numbers of flies.

One item was a "fly pipette" which was essentially a small inspirator bottle made from half of a volumetric pipette cut off in the center of the bulb. The end was worked to a tapered tip with a two millimeter opening, the stem was bent about 45°, and the bulb end was fitted with a mouth tube.

An anaesthesia tray was made by fitting a perforated cardboard false bottom in a small enamel tray. Carbon dioxide was led into the bottom part and fed up through the perforations; and a glass plate was used to cover the tray. Anaesthetized flies were poured into the tray and the fly pipette was used to sort and count out samples. It was possible to count out as many as 15 samples of 50 flies each, by sex, in an hour.

A suction apparatus was used for transferring active flies into cages and from one cage to another. The fan and motor from an old vacuum cleaner were mounted under a plywood platform in which a circular opening had been cut. The cages used were made by fitting quart ice cream cartons with cheesecloth bottoms and transparent tops; and the vacuum intake opening was just large enough to accommodate the end of a cage. When flies were to be introduced, the cage was set on the suction apparatus and the flies were poured into the open top. When flies were to be transferred from one cage to another, the occupied cage was set on the suction apparatus and, when the lid was eased off, the flies were blown to the bottom. Then a second cage was fitted on top by means of a tight-fitting collar. When the two cages were inverted, the flies were blown into the second cage. Introductions or transfers could be made at the rate of ten in four minutes.

The Experiment on the Development of Strains

Adult flies of the third generation of the X strain were used to start four experimental strains. The X strain was continued and served as the standard of comparison.

Two of the experimental strains were developed by rearing flies for five successive generations on media containing DDT. One strain, designated the L2 strain, was reared on medium prepared to contain two ppm. of DDT; and the other, designated the L5 strain, was reared on medium containing five ppm. of DDT. The media were prepared by adding appropriate amounts of acetone solution of DDT to freshly prepared standard medium before autoclaving. The other two experimental strains were developed by a selection process.

It was hypothesized that it might be possible in exposures of adults to DDT residues to use rapidity of development of toxic symptoms as the basis for selecting susceptible and resistant strains. The procedure was first, exposure of a group of adults to a DDT residue until about 10 per cent showed incoordination; second, rescue of this early-affected fraction; third, continuation of the exposure until all but about 10 per cent of the flies were in the knock-down state; and, fourth, rescue of this last-affected fraction. The two sexes were exposed and selected separately; and the rescued flies were transferred to clean culture bottles.

The two groups of flies obtained by applying the selection procedure to adults (200 females, and 200 males) of the third generation of the X strain were used to establish two strains. The strain started with the early-affected fraction was designated strain S; and the strain started with the last-affected fraction was designated strain R. Each strain was selected in six successive subsequent generations, the S strain being selected only for the early-affected fraction, and the R strain being selected for the last-affected fraction.

Ice cream carton cages served as selection exposure chambers. Each carton had the curved wall (about 75 per cent of the total inside surface) lined with DDT impregnated paper (1.0 mg. per sq. in.). The bottom of the cage was closed with cheesecloth; and the lid had a transparent insert through which a twelve inch slender glass tube extended. The progress of the exposure was observed through the transparent top; and the glass tube was used as a pipette for rescuing selected flies.

The goals of selection, the first and last 10 per cent fractions, were seldom achieved. Usually about a tenth of the rescued flies failed to recover. In the case of the S strain, this meant that there was in fact a mild selection, presumably for resistance. In the case of the R strain the selection was merely more severe than intended.

TABLE I. Mean mortalities of five strains of pomace flies in residue exposuse tests on adults of the ninth and tenth generations; and differences required for significance.

Strain		Ninth Generation[1]	Tenth Generation[2]
R		36.08	16.83
S		39.50	20.83
X		44.75	28.78
L2		30.83	18.39
L5		39.83	32.44
Differences required for significance	At 19:1	6.77	8.39
	At 99:1	9.04	11.14

[1] Half hour exposures to deposits of 1 mg. per sq. in.; six replications.

[2] One hour exposures to deposits of ⅛ mg. per sq. in.; nine replications.

All the strains were carried through ten generations. In the ninth and tenth generations replicated mortality test comparisons were made to determine the relative resistance of the five strains. The sample groups were 50 flies for each sex and for each strain, making ten tests per replication. The sample groups were exposed to DDT residues in ice cream carton cages for short periods and then were removed to clean cages and held for 24 hours. The 24 hour mortality readings were taken and analyzed statistically.

For both generations the analyses showed first, that there were significant differences (at odds of 19 to 1) between replications; second, that female flies were significantly more resistant (at odds of 99 to 1) than males; third, that there was no significant interaction of sex and strain; and, fourth, that there were significant differences between strains. The mean mortalities of the five strains, the differences required for significance, the number of replications, and the dosages used in these tests are shown in Table I.

These data show that strains R and L2 were rather highly resistant and that strain S was slightly resistant, as compared with the standard X strain. The L5 strain appears somewhat variable but not very different from the standard.

Less extensive data on adults of the third and fourth generations support this relative ranking of strains R, S, and X; but in those earlier generations the L2 and L5 strains were not shown to be significantly different from the standard.

It seems clear that the high resistance of the R strain resulted from a rather severe selective effect, and that the slight resistance of the S strain resulted from a mild selective effect. The author has, however, no adequate explanation of the results on the L2 and L5 strains. If one explains the high resistance of the L2 strain as the result of a selective effect, he is faced with the question of why the L5 strain, which was treated at a higher rate, was not even more highly selected.

It must be noted that there was an interval of four generations between the last treatments of the L2 and L5 strains and the time of testing for resistance. It appears that, perhaps, during this interval some uncontrolled factor may have acted differentially on these two strains. The author is inclined to suspect there may have been some nutritional factor involved or, possibly, some effect related to an observed mold infestation of the cultures.

It may be stated, by way of conclusion, that the selection method based on rapidity of development of symptoms was successful in producing a resistant strain but failed to produce a susceptible one.

The Experiment on Effects Produced within a Single Generation

The experiment was initiated with eggs obtained from adults of the third generation of the X strain. The eggs were allowed to hatch and develop in culture media containing DDT.

The eggs were obtained by caging several hundred flies for twelve hours (overnight) in an ice cream carton cage in the lid of which a thin layer of agar had been poured to serve as an oviposition site. Batches of 50 eggs were counted and transferred to culture bottles. (A small proportion of newly hatched larvae was included in the "egg" counts, it having been found impractical to attempt to exclude them.)

Four media containing DDT were used. These were prepared to contain one, two, three, or four ppm. of DDT by adding appropriate amounts of acetone solution of DDT to freshly prepared standard medium. Two controls were used. One was the standard (untreated) medium; and the other was acetone-treated medium. The prepared culture bottles were autoclaved to eliminate the acetone; and the cultures were held at 26±2°C. There were fourteen replications.

The number of adults of each sex emerging in each 24 hour period was recorded; and the emerged flies were set aside in clean culture bottles. The data provided information on the total number of flies emerging from each batch of eggs, and permitted the calculation of weighted average development times for each sex in each culture.

The analysis of the data on survival to emergence gave only a slight indication that DDT at the higher rates reduced survival. The means for each treatment are given in Table II.

TABLE II. Effects produced within a single generation by DDT treatments of the larval media.

Treatment	Survival to emergence. (Mean no. of adults from 50 eggs)	Length of developmental period. (Mean no. days egg to adult)	Survival from emergence to testing. (Per cent)	Resistance of adults. (Mean mortality values)
Untreated	41.9	9.50	89.8	59.96
Acetone	39.7	9.56	84.2	61.27
1 ppm. DDT	41.9	9.55	92.2	63.24
2 ppm. DDT	37.5	9.70	89.0	65.74
3 ppm. DDT	38.1	9.61	88.6	60.94
4 ppm. DDT	37.6	9.85	89.7	49.11[1]

[1] significantly different from other treatments at odds 19 :1.

The analysis of the data on development time showed first, that the males took significantly longer (about 1/3 day, odds of 99 to one) than females under all treatments; second, that there was no significant interaction of sex with treatment; and, third, that there was a rather strong indication that the DDT treatments increased the length of the developmental period for both sexes. The means for each treatment are shown in Table II.

On the sixteenth day after egg collection the adult flies that had been produced were subjected to DDT residue exposure tests to discover whether the treatments had affected their resistance. Six replications of these tests were run. As the sample groups were rather small and of varied size, the mortality data were expressed as percentages and transformed to arc sine values for analysis.

The analysis showed first, that the males were significantly less resistant (at odds of 99 to 1) than the females under all treatments; second, that there was no significant interaction of sex and treatment; and, third, that there was significantly greater resistance (at odds of 19 to 1) in the flies that had been reared on medium containing four ppm. of DDT. The mean values for the residue exposure tests are shown in Table II.

The records were examined to discover whether there had been any differential in survival of adults of the six treatment-groups in the interval between emergence and testing. These survival rates are shown in Table II. It is apparent that there were no appreciable differences.

Correlations between sets of means were run to discover whether the results of the residue exposure tests were related to any of the other measured effects of treatment. There was a rather strong indication that increased resistance was related to increased length of the developmental period; and there was a very slight indication that increased resistance was related to decreased survival from egg to adult. There was no indication of any relationship between resistance and survival in the interval between emergence and testing.

In regard to the indicated relationship between length of developmental period and resistance it should be noted that, when the developmental period was longer, the flies, at the time of testing, were necessarily younger in terms of age-as-adults. And it may well be that the apparently increased resistance of the four ppm. flies was merely a reflection of an age difference, perhaps acting in conjunction with a selective effect.

The indication of a lengthened developmental period in flies reared on media containing DDT agrees with observations reported in 1950 by Kalina (1) who reared pomace flies on medium to which five ppm. of DDT had been added in carbon tetrachloride solution.

Kalina reported also that in his experiment all flies died apparently of DDT poisoning at about the time of emergence. In the author's experiment which differed as to rate of treatment, method of treatment, and method of rearing, nothing more than mild toxic symptoms was ever observed; and there was no consistent relationship of these mild symptoms to rate of treatment.

An Experiment on a Temperature Effect

One small experiment was run to discover whether, as suspected, the temperature at which flies were held after exposure to DDT residues affected the 24 hour mortality readings.

A double series of sample groups of flies of the fourth generation of the L5 strain and the corresponding generation of the X strain was exposed to DDT residues. One series was held for 24 hours at 26±2°C. while the other series was held for 24 hours at about 29°C. There were only three replications.

The analysis gave a strong indication that mortality was less for both sexes of both strains at the higher holding temperature.

The author believes that small temperature variations were in part responsible for inter-replications differences in the experiments reported above.

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The Effect of the Lesser Clover Leaf Weevil on the Seed Yields of Mammoth Red Clover

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The lesser clover leaf weevil, *(Hypera nigrirostris*, Fab.), is sometimes known as the clover bud worm, which is more descriptive of the nature of the injury it causes.

This insect was first found in the Eastern United States and Canada about 1875, and it is believed to have been introduced from Europe. It has spread now throughout the midwest and into the Pacific Northwest. Since 1915 it has increased very rapidly in abundance and destructiveness.

Adults of this species overwinter in the crowns of the clover plants, but are found in greater abundance in woodland areas, along fence-rows and roadsides wherever sufficient trash occurs to give protection over the winter. About the time clover begins to grow in the spring, the weevils fly from hibernation and feed for a few days on the leaves of the clover. The females lay the eggs in small slits cut in the clover stems or in the axillary and terminal buds. The eggs are usually deposited singly during the month of April. Hatching occurs in from two to three weeks and the young larvae begin feeding in the stems and buds. Feeding in the stem often causes the stem above the point of feeding to wilt and die whereas feeding in the buds, which is most common, seriously injures or destroys the developing buds. The larval period lasts from 20 to 25 days. When mature, the larvae are greenish-white, legless grubs with a dark head and a dark line across the body just back of the head. Cocoons are spun in the trash on the ground around the base of the plant, but are more commonly found on the part of the plant where the larvae have been feeding. The adults emerge from the cocoons in from five to twelve days. Emergence is generally completed about ten days before hay cutting begins. The newly-emerged adults are brown, but begin to show the greenish color after one or two days, and by the third or fourth day are a pronounced grass green. The newly-emerged adults feed on the clover for a period of two to three weeks, gradually becoming less abundant as they seek winter quarters and by mid-July most of them have left the field.

In 1952 two experiments were carried out to study the effect of the control of spittle bug nymphs on seed yield of Mammoth red clover. In addition to the spittle bug infestation, a rather heavy infestation of the lesser clover leaf weevil also developed.

The first experiment consisted of plots of clover 40 x 800 feet, which were treated on May 8 with the following insecticides and the dosages in pounds of active ingredients per acre: methoxychlor, 1.82; heptachlor, .91; dieldrin, .91; and DDT, 1.82; and an untreated plot. All materials were applied as emulsifiable concentrates by a tractor mounted weed sprayer and the treatments were replicated six times.

The second experiment consisted of plots 20 x 40 feet, with 16 treatments applied May 12 and randomized in six replicates. The following materials and dosages in active ingredients per acre were applied with a

TABLE I. Lesser clover leaf weevil populations and damage to seed yields of Mammoth red clover. Eminence, Indiana. 1952.

	Dosage	Stems Infested	Weevils per infested stem	Weevils per 100 stems	Damage buds per 100 stems	Heads per square foot	Seed yield per acre	Seeds per head
	Lbs.[1]	Pct.	No.	No.	No.	No.	Grms.	No.
Methoxychlor	1.82	41.3	.39	16.6	81.7	91.7	204.8	12.9
Heptachlor	.91	40.0	.59	24.0	72.0	76.6	207.6	15.0
Dieldrin	.91	28.0	.26	6.0	47.3	97.6	216.5	12.5
DDT	1.82	40.7	.38	14.0	84.0	87.6	208.0	13.4
Untreated	....	54.0	.56	30.0	118.0	79.6	191.8	13.3
Average	....	40.8	.43	18.1	80.5	86.6	205.7	13.4
Least required	19:1	14.5	n.s.	15.0	38.2	n.s.	n.s.	n.s.
Significant difference	99:1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[1] Active ingredient in pounds per acre. Materials applied by a tractor mounted weed sprayer in 10 gallons of water per acre, applied May 8.

small plot sprayer: Heptachlor at rates of .26, .47, and 1.03; DDT at .52, .98 and 2.00; DDT and C110[1] at the rates of .53 and .18, 1.09 and .36, and 2.03 and .67; methoxychlor at .49 and .74; BHC at .58; toxaphene at 2.12; and an experimental material H at .28 and .53.

Data on the lesser clover leaf weevil were obtained from 25 stems selected at random from each plot. The numbers of stems showing infestation, the numbers of axillary and terminal buds damaged, and the numbers of larvae, pupae and adults present were recorded. In addition, the numbers of spittle bug nymphs per square foot were counted in the second experiment. Seed yields estimates were obtained by taking two samples of three square feet each in each plot in the first experiment, and one sample of three square feet in each plot in the second experiment.

The data for the first experiment are given in table I and for the second experiment in table II.

From table I the most effective material for controlling the weevil population was dieldrin, while DDT and methoxychlor were fair. The dieldrin treatment also had the highest numbers of heads per square foot and the highest seed yield.

In table II, the insecticide giving the best control was DDT at 2.0 pounds per acre. By comparison it will be noted that DDT at a slightly lower rate in the first experiment gave very similar results. The difference of four days time in the treating of the two experiments probably had some effect.

Table III lists the between treatment correlation coefficients for the various data taken. In table IV are given the b values for the unit changes in the dependent variables for each unit change in the independent variable.

Spittle bug nymphs per square foot were not significantly correlated with either heads per square foot or yields of seed. There was no significant correlation between spittle bug populations and lesser clover leaf weevil abundance, indicating that the chemicals which controlled one species did not necessarily give control of the other.

Per cent of stems infested by the lesser clover leaf weevil were highly correlated with damaged buds per 100 stems, heads per square foot, and seed yield. For each per cent increase in infestation, the number of damaged buds per 100 stems increased 2.25; heads per square foot decreased .61; and seed yield decreased 2.61 pounds per acre.

Weevils per 100 stems are significantly correlated with per cent stems infested, damaged buds per 100 stems, heads per square foot, and seed yields. For each increase of one weevil per 100 stems the per cent of stems infested increased .82 per cent; damaged buds per 100 stems increased 1.79 buds; heads per square foot decreased .71 heads; and seed yields decreased 2.73 pounds per acre.

Weevils per infested stem were significantly correlated with damaged buds per 100 stems, heads per square foot, and seed yields. For each increase of one weevil per infested stem there was an increase of 88.82

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[1] C110 had indicated a synergistic action with DDT in previous experimental work (Dow Chemical Company).

TABLE II. Lesser Clover leaf weevil populations, and damage to seed yields of Mammoth red clover. Eminence, Indiana. 1952.

	Dosage	Stems infested	Weevils per infested stem	Weevils per 100 stems	Damaged buds per 100 stems	Heads per square foot	Seed yield per acre	Seeds per head	Spittle bug nymphs per square foot
	Lbs.[1]	Pct.	No.	No.	No.	No.	Lbs.	No.	No.
Heptachlor	.26	58.0	.51	29.5	120.7	80.4	143.1	9.8	28.2
Heptachlor	.47	49.3	.72	36.5	100.0	75.7	147.9	10.9	27.3
Heptachlor	1.03	43.3	.52	22.6	83.3	78.9	165.4	11.6	21.0
DDT	.52	50.0	.42	21.8	92.0	92.5	176.2	10.7	61.3
DDT plus	.53								
C110	.18	48.0	.69	33.2	88.0	83.5	173.0	11.7	61.5
DDT	.98	41.3	.59	25.5	82.7	76.7	183.3	13.8	39.2
DDT plus	1.09								
C110	.36	50.7	.60	32.5	104.7	77.4	154.1	10.9	32.0
DDT	2.00	44.7	.39	18.5	86.7	91.7	191.1	11.9	27.7
DDT plus	2.03								
C110	.67	35.3	.59	20.5	63.3	91.6	170.6	10.3	22.5
Methoxychlor	.49	52.7	.55	29.8	96.7	76.4	136.9	10.0	29.2
Methoxychlor	.74	53.3	.55	31.3	104.8	73.1	160.6	12.1	37.3
Experimental H	.28	56.7	.63	37.2	105.3	78.7	143.2	10.1	48.7
Experimental H	.53	62.7	.68	41.3	116.0	65.9	117.7	9.8	46.5
Toxaphene	2.12	55.3	.75	41.8	116.0	73.8	113.2	8.4	27.0
BHC[2]	.58	60.7	.62	35.8	120.0	85.7	159.0	10.1	3.2
Untreated	....	56.7	.58	32.7	133.3	69.1	134.1	10.9	51.5
Average	....	51.2	.59	30.7	100.8	79.4	154.3	10.8	35.2
Least required	19:1	12.2	n.s.	13.2	29.9	n.s.	45.0	n.s.	22.5
sig. diff.	99:1	16.2	n.s.	17.5	39.7	n.s.	n.s.	n.s.	29.8

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[1] Active ingredient per acre. Materials were applied on May 12 with a small plot sprayer in 10 gallons of water per acre.
[2] Gamma isomer

TABLE III. Correlation coefficients for lesser clover leaf weevil infestations, populations, and seed yields of Mammoth red clover at Eminence, Indiana. 1952.

	Percent infested	Weevil per infested stem	Weevil per 100 stems	Damaged buds per 100 stems	Heads per square foot	Seed yield per acre	Spittle bug nymphs per square foot
Percent infestation	....	XXX	.854**	.943**	—.643**	—.774**	XXX
Weevils per infested stem	XXX	....	XXX	.520*	—.720**	—.705**	XXX
Weevils per 100 stems	.854**	XXX	....	.787**	—.781**	—.846**	XXX
Damaged buds per 100 stems	.943**	.520*	.787**	....	—.654**	—.714**	XXX
Heads per square foot	—.643**	—.720**	—.781**	—.654**	....	—.700**	.138
Yield of seed per acre	—.774**	—.705**	—.846**	—.714**	.700**	....	.015
Spittle bug nymphs per square foot	XXX	XXX	XXX	XXX	.138	.015	....

* Statistically significant
** Highly statistically significant

TABLE IV. Rates of change in the dependent variable values for each unit change in the independent variable expressed as b-values.

Independent variable	Dependent variable			
	Damaged buds per 100 stems	Heads per square foot	Seed yields per acre	Stems infested
	No.	No.	Lbs.	Pct.
Percent stems infested	2.25**	—.61**	—2.61**	....
Weevils per infested stem[1]	88.82*	—48.79**	—169.80**	XXXX
Weevils per 100 stems	1.79**	—.71**	—2.73**	.82**
Damaged buds per 100 stems	....	—.26**	—1.01**	XXXX
Heads per square foot	XXXX	....	—2.49**	XXXX

* Statistically significant

** Highly statistically significant

[1] The rates of losses for this dependent variable are exceptionally high due to the relatively low population. Since pupation had already started, counts made 2 to 3 weeks earlier would probably indicate a much larger population of weevils with subsequent reduction in the amount of damage per weevil.

damaged buds per 100 stems; heads per square foot decreased 48.79 heads; and seed yields decreased 169.8 pounds per acre.

The numbers of damaged buds per 100 stems were significantly correlated with heads per square foot and seed yields. For each damaged bud increase, the numbers of heads per square foot decreased .26 heads, and the seed yield decreased 1.006 pounds per acre.

Heads per square foot were significantly correlated with the yield of seed as should be expected. For each head per square foot increase, the seed yield increased 2.488 pounds per acre.

It should be kept in mind that these data are the results of only one year's study and for that reason may be modified by future studies. The value of the insecticides used might also be increased with earlier application or correct timing. But it is evident that the lesser clover leaf weevil can cause heavy losses in seed yields of Mammoth red clover.

GEOLOGY AND GEOGRAPHY

Chairman: T. F. Barton, Indiana University

Clifford Adams, Hanover College, was elected chairman for 1953

ABSTRACTS

Mapping of the Beech Creek limestone in southern Indiana.[1] T. G. Perry, Indiana University.—During the past two field seasons the Beech Creek limestone (youngest formation of the Upper Mississippian Lower Chester group) has been mapped throughout its Indiana outcrop belt, which extends from the Ohio River to north-central Owen County. This paper is restricted to a consideration of the formation south of the East Fork of White River. Numerous structural anomalies of low character and many previously unknown outliers and inliers have been recorded as a result of this study. A careful consideration of its physical and paleontologic characteristics, among which are the distinctive dark-gray, hard, dense, gastropod-bearing limestone in the basal 2 to 6 feet of the formation, the conspicuously large crinoid stems, and the rare occurrence of oolites, enables the Beech Creek limestone to be distinguished from other Chester limestones. Problems pertinent to the Beech Creek limestone and which merit further consideration are confirmation of its correlation with the Chester section in Illinois and a systematic study of its fauna.

The relationship of minor element deficiencies to soil type in Indiana. S. A. Barber, Purdue University.—The presence of available plant nutrients in a soil is dependent upon the geologic origin of the parent material and upon the subsequent degree of weathering. The availability of minor elements is also reduced by organic matter in the soil since it tends to tie them up in an unavailable form. Manganese and boron are the only two minor elements which are deficient in an appreciable number of soils. The deficiency of these minor elements is related to soil type. The severity of the deficiency is influenced by soil pH, the nature of the crop and weather conditions.

Sequent occupance of the Calumet Region of Northwest Indiana-Northeast Illinois. Fourth (present) Stage. Alfred H. Meyer, Valparaiso University.—This is the fourth and final stage of sequent occupance study of the Calumet, the first, second, and third having been previously presented to the Academy. The present stage is one of Agricultural and Industrialization Specialization, Conurbanization, and Planning.

The most remarkable phenomenon of settlement of the present period is the expansion of the western Calumet communities into one large Chicago metropolitan region. A map prepared to show this reveals a southward and eastward extension and consolidation of suburban communities. This reflects the phenomenal 20th Century development of the steel and related industries centered about the Gary-East Chicago- Indiana Harbor-South Chicago region.

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[1] This paper is presented with permission of the State Geologist, Geological Survey of Indiana.

Today some 200 industries, manufacturing over 1,000 products, are located in this beach-dune sand region, whose marshes as recently as a half century ago were the haven of countless wild fowl and fur-bearing animals. The major industries are grouped in the conurban Chicago-Gary area on sites especially favored by rail and/or water transportation facilities—along the shore of Lake Michigan; both sides of the Grand Calumet River, especially in its lower course; the vicinity of Lake Calumet; and along the course of the Indiana Harbor Canal.

Now it is significant to note that within the last decade the population of the metropolitan area outside of Chicago has grown, on a percentage basis, over four times as fast as that within the city. During the same period Chicago has attracted three times as many manufacturing plants as the area outside of the city. This "Problem of Peripheral Population in Pursuit of Propinquity," as Stanley Berge has characterized it, must be resolved by a comprehensive survey of the region, and the application of sound regional and city planning principles towards the development of a land-use pattern in harmony with the geographic structure and function of the region.

A preliminary evaluation of the forecasts of the Hoosier Weather Prophet, Mark Purcell. BENJAMIN MOULTON, Butler University.—Among the many prophets of weather that are revealed in Indiana history the most recent is Mark Purcell of Rushville. During the past several years his forecasts have attracted front page positions on the leading daily papers in the state. His success as a weather prophet is highly acclaimed by many. Through a number of technical devices forecasts of Purcell were analyzed. Difficulties arose in interpreting the generalities of the forecast, time distribution and some unusual terminology. An attempt was made to be as fair as possible. Statistics of actual weather conditions show the forecasts to be subject to great errors. Actually, although the stated method of determining forecasts is recognized, Purcell probably, like anyone else, would have greater success through forecasts based on probability formula.

Brazil, a regional interpretation. PAUL F. WACHHOLZ, Staff College, Fort Leavenworth, Kansas.—Brazil, greater in area than the United States and the most populous Latin nation of the world, has been our traditional South American ally. Despite its vital contributions to Allied victory in World War II, only a few specialists in the United States possess the precise knowledge to evaluate her human and economic potential.

The purpose of this survey is to surmount the barriers of Brazil's cultural and geographic remoteness by a series of impressionistic sketches of her varied regions.

The regions treated in this survey are:

1. Amazonia—The world's largest fluvial network and selva complex.
2. The "Backlands" of the Northeast—Brazil's semi-arid "Disaster Zone."

3. The Central Western Plateau—The "Pivot Area" of South America.
4. The "Great Marsh"—The vast seasonal inland fresh water sea.
5. The Southeastern Ranges—The "Backbone," Western Hemisphere strategic minerals storehouse.
6. The Southern Plateaus—The "Workshop and Marketbasket" of Brazil.
7. The Atlantic Seaboard—Brazil's Urban "Archipelago."

Extra-regional factors must be recognized for an appreciation of the contrast of Brazil's nationality with the numerous political entities of the Spanish American world.

The karst topography of Puerto Rico. ROBERT N. YOUNG, Indiana University.—A geologist has classified the karst area of northwestern Puerto Rico a coastal plain and a physiographer has called it a plateau, yet parts of the region are much too rugged to warrant either designation. In a typical square mile of some of the roughest karst, the local relief is 560 feet, although ninety-five per cent of this area has slopes greater than thirty degrees. Over half of the slopes are more than forty-five degrees and some more than sixty degrees. This landform is one of extremely rugged hills, not "plain" or "plateau."

In contrast, some Puerto Rican karst is similar to a square mile near Mitchell, Indiana, where the local relief is one hundred feet but where there are few, if any, slopes of thirty degrees. In consideration of this, Puerto Rican karst varies sufficiently to encourage one to ponder the meaning of the term "karst."

Manufacturing in intra-city localities. BERNARD H. SCHOCKEL, 318 Third Street, Aurora.—The role of conveyance ways within a city to its manufacturing has been stressed by a number of geographers, but the role of intra-city locality in manufacturing has thus far received slight attention. The role of such locality can no longer be ignored in correlations of factory distribution within a city as is attested by this study. But much investigative work remains to be done. There is strong alignment of factories with respect to inner versus outer localities, and with respect to site, situation, and age localities. In isolated cases there is correlation with dedication localities. It is inferred that there is also correlation with localities based upon evolutionary stage.

The use of geographical knowledge in the field of direct selling. WALTER BEALE BLAIR, Butler University.—It is the purpose of this paper to describe another of the recurring uses to which geography can, and has, been applied. The field of Direct Selling and the market areas affected by such enterprises are dwelt with to some length in close relation to the human geography of the locality. The desire for homogeneity in each prospective sales territory is the ambition of the selling agent. The task of bounding such a territory in relation to family units, physical, and cultural boundaries is the task of the geographer.

The sources of statistics to be used in population data of our fluid society are many and varied, as to their reliability. Work by people in the field is the only valid way to assure a reasonable amount of accuracy. However, such work is prohibited because of the financial investment. Rivers, streams, rail lines, parks, etc., are combined with standard of living types to draw the many cultural boundaries. The minorities, wherever possible, are usually separated from other classes. The usefulness of geographical knowledge in a field such as this is obvious.

Some contributions to a geomorphology of the Mohawk Region. HELMUT BLUME, Visiting Lecturer from Marburg University, Germany, Valparaiso University.—The Mohawk region is defined as the west-east stretching lowland between the Adirondacks and the Alleghenies in Central New York. Although heavily glaciated and covered thickly with glacial drift, the preglacial landforms of the Mohawk area are nevertheless recognizable. The common explanation of landform development is that the plateaus above the Allegheny Front and above the isolated Tug Hill Cuesta between Black River and the Mohawk, as well as the surfaces of the Adirondack Mountains (all in a rather similar altitude of 2,000± feet) represent the Schooley Peneplain. It is assumed by all authorities on the subject that the sedimentary rock cover formerly reached further to the north, and by its removal the hidden pre-Cambrian surface became uncovered, as represented by the southern slopes of the Adirondacks.

The most impressive geomorphological features are in the Mohawk area: peneplained surfaces, independent of rock structure, in the Adirondacks; cuestas and surfaces, dependent on rock structure, in the Allegheny region. It is the purpose of this paper to outline some general ideas about the relations of these two areas which are in contact in the Mohawk region.

Both types of landforms are combined in one feature, the foot level of the Adirondacks, which is the lowest level of a "Piedmonttreppe" on the crystalline rocks; but while continuing upon the sedimentary rocks it is here a structural surface ("Landterrasse"). The foot level is bordered on one side by the lowest "Piedmontslope," which leads to the higher surfaces (Schooley). On the other side it is bordered by the lowest cuesta.

The possibility of reconstruction of surfaces from the peneplained area to that of structural dependence is denied. It is believed that since the pre-Cambrian rocks became uncovered in the center of the Adirondack uplift, a feature corresponding to the present foot level combined the two areas of different landforms at all times. The former foot levels are to be found in the higher surfaces of the Adirondacks today because of the uplift of the area. On the other hand, a result of the uplift is the removal of the sedimentary rock cover, the cuestas wandering away from the center of the uplift.

The writer believes that the pre-Cambrian surface is not to be seen in the present landforms. The southern Adirondacks represent a series of peneplains or erosion surfaces which is called a Piedmonttreppe.

Milk sheds of Indiana. JOHN T. HUDSON, Falls City, Nebraska.—During a survey on the milk sheds of Indiana, I found that the Ft. Wayne area is an extremely good example of those that are found in the state.

The present territory that Ft. Wayne draws from, 14 counties surrounding Allen County, used to have quite a bit of competition from Toledo, Detroit, and Cleveland. Today, the present price paid by the Producers Association makes a price above that the other sheds can afford to pay and still transport it to the manufacturers. Also, due to the threat of the manufacturers moving back into the area, the milk price paid by the Ft. Wayne association remains high. From 1947 through 1951 Ft. Wayne paid more than others by about 15¢ per 100 pounds.

An interesting thing has taken place within the last ten years. By improvement of the dairy herds, the number of pounds of butter fat produced per cow has increased so that it now takes fewer cattle to produce more milk than in 1940. Also, today a relatively small amount of cream is sold by the producers in comparison to the amount of whole milk. This may be due to the increased use of margarine on the dinner table. Butter is still three times as high as margarine, yet does not contain the guaranteed amounts of amino acids as margarine is required to do.

So the total number of dairy cattle has decreased, yet milk production has increased. Per capita consumption has increased from 16 to 26½ pounds from 1940 through 1950. Farmers are buying registered cattle. More milk is being sold as Grade A. We are given better milk, more of it, and at relatively less cost to farmers per pound of whole milk.

Current Directions Indicated by Cross-bedding in Deposits of Early Mansfield Age in Southwestern Indiana[1]

C. L. Bieber, DePauw University

One of the most striking features of the massive sandstone facies of the lower part of the Mansfield formation is the prominent cross-bedding common to many exposures in southwest Indiana. Individual cross-bedding planes generally dip between 20° and 30° and are a fraction of an inch to several inches apart. They are included in nearly flat-lying beds which range between 6 inches and 2 feet in thickness. On any one outcrop the direction of the cross-beds may vary as much as 90°, and in some cases more. Locally, however, most prominent torrential cross-beds show little variation in direction of dip.

Because the massive sandstones are not continuous laterally, it is generally believed that the sand was deposited in channels on the erosion surfaces on Mississippian rocks. Torrential cross-beds, which dip in the direction of flow of the ancient streams, lend weight to this belief. Current directions of these post-Mississippian-Pennsylvanian streams, as interpreted from cross-beds, were toward the southwest.

Where the cross-beds are numerous, the sandstone is more likely to be medium- to coarse-grained. White quartz pebbles that range from 5 mm. to 20 mm. in diameter are scattered in the Mansfield sandstones from northern Martin County southward to the Ohio River. The quartz pebble conglomerate is commonly associated with torrential cross-bedding.

Seventy-six compass readings were taken on direction of dip at 39 different exposures spaced throughout the area. Readings were taken only on cross-beds that show definite direction of dip. All outcrops could not be visited, but observations are so spaced that the plotted directional averages probably represent a fair interpretation of current directions.

Conclusions

1. Lower Mansfield currents in the main flowed toward the southwest with an average direction of S. 40°W.
2. The sediments of early Mansfield age, largely silica sand with sparing quartz pebble conglomerate, were deposited in fresh water in channels. Locally, basin sediments are included.
3. The silica sands are largely a product of reworked Chester sands of the immediate area and of transported quartz fragments from the Canadian Shield and Appalachian regions to the north and east.
4. Quartz pebbles of the conglomerates may have their origin in part from reworked geode quartz (1). Geodes of lower Harrodsburg and upper Borden (lower Mississippian) age are numerous along the outcrop belt 25 miles northeast of the main conglomerate area of Martin County. Fragments of geodes are found sparingly in the conglomerate; however, most of the pebbles have likely come from igneous rock sources to the north and east.

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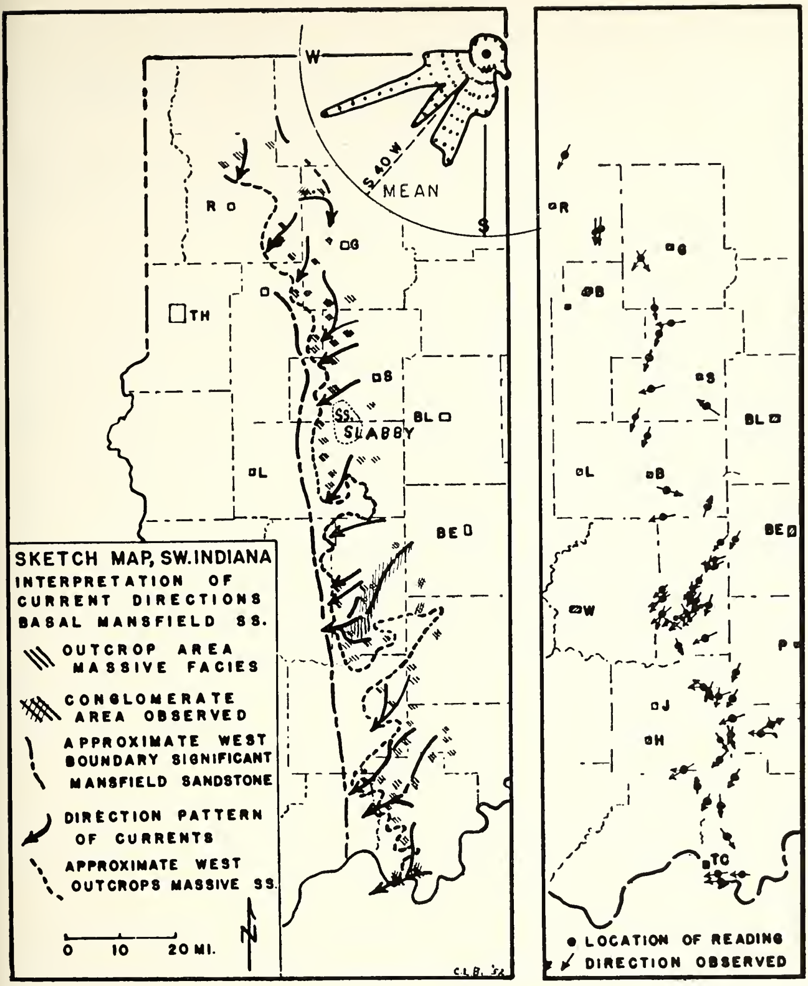
[1] Published with permission of the State Geologist, Geological Survey, Indiana Department of Conservation.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SKETCH MAP, SW. INDIANA
INTERPRETATION OF CURRENT DIRECTIONS BASAL MANSFIELD SS.
OUTCROP AREA MASSIVE FACIES
CONGLOMERATE AREA OBSERVED
APPROXIMATE WEST BOUNDARY SIGNIFICANT MANSFIELD SANDSTONE
DIRECTION PATTERN OF CURRENTS
APPROXIMATE WEST OUTCROPS MASSIVE SS.
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Fig. 1. Current directions indicated by cross-bedding in deposits of early Mansfield Age in Southwestern Indiana.

5. Torrential cross-beds are in the lower massive facies of the Mansfield formation. Basin facies of the same zone show little cross-bedding with no apparent average of directions.
6. Upper Mansfield shaly and silty sediments are in general of basin and near-shore types. The limited sandstones have few distinct cross-beds that indicate directional patterns for currents.

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Indiana's Weather: Some Extremes and Advantages

Stephen S. Visher, Indiana University

Indiana's weather is characterized by frequent and often wide fluctuations from average conditions. Some extremes presented in *Climate of Indiana*[1] are extracted here and are supplemented by several records established since it was completed, in 1940.

High Temperatures

The highest temperature officially recorded in Indiana in the shade by the U. S. Weather Bureau was 116°, on July 15, 1936, at Collegeville, near Rensselaer, Jasper County, about 45 miles south of Lake Michigan. During that hot, dry spell, several nearby stations had temperatures almost as high, as did Shoals in southern Indiana (114°). Prior to 1936, the state's highest temperature record was 113°, in southern Indiana.

Official temperatures of 100° or more have been recorded somewhere in Indiana in seven months of the year. The highest in July is 116°; in August, 111°; in June, 111°; in September, 108°; in May, 103° (at several places in S. Indiana; 99° at Fort Wayne); in October, 100°; and in April, 100°. The state's high records for the other months are: November, 91°; December, 77°; January, 80°; February, 83°; March, 91°.

The frequency of high temperatures is much greater in southern than in northern Indiana: for example, about three times as many days of 90° or higher.

Low Temperatures

The lowest official temperature record in Indiana is —35°, established on February 2, 1951, at Greensburg, in southeastern Indiana, 35 miles from the Ohio River. Scottsburg and Salem, still farther south, had temperatures almost as low. Previous to 1951, the state record had been —33°, established in Lafayette, in northwestern Indiana (January 2, 1887).

Official temperatures of zero or below have been recorded somewhere in northern Indiana from late November to early March. By months: November had —9° or —10° on the 25th in 1950 at many northern stations; December has had —30°; January, —33°; February,—35°; and March, —19° (Goshen, March 8, 1943). April has had a temperature of 7°, May of 20°, June of 30°, July of 37°, August of 33°, September of 21°, and October of 8°.

Temperatures below —10° occur fully five times as often in the northern part of the state as in the southern, and persist much longer.

The dates of the last killing frost in spring and the first in autumn are highly significant aspects of low temperatures. A killing frost has occurred as late as May 25 even in much of southern Indiana (1925), and in June in northern Indiana. The first killing frost of the autumn has occurred on September 14 widely in central and northern Indiana. The most spectacular early frost was on July 29, 1936, on low muck land in northern Jasper County, the county where the all-time high temperature record of 116° was established exactly two weeks earlier. (The extreme aridity of that spell permitted a rapid escape of heat at night, and the dry muck largely prevented the movement of heat from the warm soil beneath.)

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[1] S. S. Visher. 1944. Climate of Indiana, Indiana University Press, Bloomington, 511 p.

Snowfalls

As to snowfall records: 107 inches fell at LaPorte, near Lake Michigan, in 1929, and 100 inches in 1924. South Bend received 80 inches in 1914; Valparaiso, 65 inches in 1930. In central Indiana, Anderson established a record of 56 inches in 1914. The records in southern Indiana are 67 inches at Vevay, on the Ohio River in Switzerland County, in 1917, and, at the southwestern corner of the state, 47 inches at Mt. Vernon, Posey County, in 1918. For the entire state, the fall in January, 1918, averaged 25 inches, and 16 inches in February, 1910 and 1914. December got 13 inches in both 1917 and 1895; November got 7.6 inches in 1950; March got 16 inches in 1906; April got 4 inches in 1920; May got 1.3 inches in 1923; and October got 1.7 inches in 1917.

Indianapolis once got 30 inches of snow in a single month (March, 1906), and 22 inches in another month (January, 1918), while 21 inches fell in February, 1910, and in December, 1895. November got 10 inches in 1932, April 7 inches in 1886, May 2.4 inches in 1897. In one day, Indianapolis once got 12 inches (March 19, 1906).

Some places sometimes go through a winter with little snowfall; for example, the southern third of the state had an average of less than 2 inches in 1919, in contrast to 41 inches in 1917.

Heavy Rainfalls

Although, on the average, a total of approximately 39 inches of moisture is received per year in Indiana, occasionally little more than half that amount falls, and sometimes nearly twice that much. Two Weather Bureau stations, one at the southeast and the other in the northwest, have received in an entire year less than 19 inches (Valparaiso, 18.1 in 1899, Brookville, 18.7 in 1934). Conversely, annual totals in excess of 70 inches have been received at several southern stations. The highest record for a calendar year is 97.4 inches for 1890; the twelve months, November 1, 1889-October 31, 1890, received 103 inches both at Marengo, Crawford County, near the Ohio River. In the thirty days, December 27, 1936-January 25, 1937, 33 Indiana weather stations near the Ohio River received more than 15 inches of rain, five of them received from 20 to 22.4 inches. This deluge contributed to the great flood of January, 1937.

Three southwestern Indiana stations have received 10 inches of rain in a day (24 consecutive hours): Princeton, Gibson County, 10.5 inches on August 6, 1906; Huntingburg, Dubois County, 10.0 inches on January 5-6, 1895; and Elliston, Greene County, 10.0 inches on August 15-16, 1949. Two northern stations have received 7 inches in 24 hours (Valparaiso and Monticello), and several southern ones have had approximately seven inches (Indianapolis, Columbus, Bloomington, Butlerville and Marengo).

In two or three consecutive days, total falls of 8 to 11 inches have fallen at Evansville, Richmond and Hammond (as well as at the three which received 10 inches in one day).

Within five minutes, rainfalls of an inch are occasional in Indiana; in 15 minutes, two inches have fallen in Indianapolis; in 20 minutes, 4 inches at Hartford City. (Falls in three hours of more than eight inches have occurred at some stations not far from Indiana, and hence might occur in Indiana. Michigan has one 24-hour record of 14.8 inches, while New York, Pennsylvania and West Virginia each have records of more than 16 inches.)

Sunshine and Clouds

The amount of sunshine received varies widely from day to day, as well as from summer to winter. The average December-January day has about three hours of sunshine in northeastern Indiana, about four hours in southwestern; the average summer day has about ten hours in both northern and southern Indiana. In winter, cloudiness is common—occasionally there is almost no sunshine for several consecutive days. In summer, however, few days are continuously cloudy, and sunshine is much more intense than in winter. In Indianapolis, in both December and January, there are an average of about ten days which are sunless, in contrast to none in July and practically none in June and August.

Thunderstorms

About 200 thunderstorms occur annually in Indiana, but each covers only part of the state; any locality is crossed by an average of about fifty per year. Few occur in winter, almost none in northern Indiana. During the summer, an average of two or three pass near each week. Occasionally, two hit per day, and very rarely three. Conversely, weeks sometimes pass without a thunderstorm in a given locality, or without rain, as most summer rain is induced by thunderstorms.

Advantages of Indiana's Weather

The foregoing listing of extremes of temperature, etc., which have occurred clearly proves that Indiana's weather is by no means uniform or equitable. The variability or unpredictability of the weather, which is the aspect to which most people object, is far less harmful than many believe. Indeed experts who have made special studies of the subject consider variability distinctly advantageous. Regions which lack considerable weather variability are definitely handicapped. One of the advantages of variability is that it is stimulating to mind and body, whereas monotony is enervating. Another advantage is that it puts a premium on alertness and achievement. In regions that lack weather variability, people often "let things slide," say "I'll do it tomorrow." Procrastination is often "reasonable" where tomorrow's weather will presumably be like today's. Here, on the other hand, it is more logical to "do it today," as the weather may be worse tomorrow.

The numerous distressing aspects of our weather, including hot spells, cold spells, unseasonable frosts, floods, drouths, and storm, all put a premium on courageous persistence, on wise planning, and on the ability to make rational adjustments to unexpected conditions. Variability or unpredictability is therefore more harmful to inactive people than to alert ones. Sharp weather changes require numerous adjustments to reduce suffering and loss. As wise adjustments require thought and action, and encourage forethought, frequent weather changes are stimulating.

There are numerous evidences that frequent changes of weather are relatively conducive to mental activity and hence to an advanced civilization. Regions which have relatively uniform weather generally have mostly "easy-going" people. Unless migrants from more stimulating regions comprise an important part of the population, such "pleasant" regions are characteristically backward, although they appeal to many elderly and sluggish people. Indiana's climate is more suitable for young, vigorous people than for elderly ones.

During most of the year, the weather of Indiana is close to that found by much evidence to be best for civilized man. The temperatures are within the desirable range, 40° to 65°, the humidity is favorable, the wind is moderate, the sunshine is satisfactory, and the variations from day to night and from day to day are sufficient to be stimulating, without being excessive. When excessive departures from normal do occur, we should "make the best of them," and should appreciate that they occur only intermittently.

When compared with that of other parts of the world, our weather rates relatively high. To be sure, it sometimes is too hot in summer and too cold in winter, and there are occasional spells that are too wet or too dry. But no other part of the world lacks serious defects. Vast areas are much colder or much hotter, much drier or much wetter, and less satisfactory as to sunshine and winds. The more one knows about the weather of other regions, the better one realizes that Indiana's weather, despite its imperfections, is comparatively suitable to civilized man. It is doubtful if one-eighth of the world fares better. Indeed, one of the greatest experts, Ellsworth Huntington, concluded that Indiana is in the best one-tenth of the world in this respect.

Pre-Cambrian Rocks Encountered in Test Holes in Indiana

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Introduction

The pre-Cambrian basement rock complex in Indiana has been reached in six test holes drilled for oil and gas in Wayne, Henry, Jay, Howard, and Allen Counties, on the north and northwest flanks of the Cincinnati Arch (Fig. 1). The purpose of this study is to provide petrologic information on the basement complex in Indiana. Samples obtained from six holes that are only a few inches in diameter and that are scattered through an area of about 2,300 square miles obviously cannot be representative of the pre-Cambrian rocks. In addition, although one hole penetrated 468 feet of granite, the other holes extended 100 feet or less into the basement complex. Despite this scarcity of samples, the material from these test holes provides our only specific knowledge of the pre-Cambrian rocks beneath Indiana, and must be the point of departure for any additional study.

Recent geophysical investigations in Indiana have increased the need for information on the basement complex. An aeromagnetic survey of Indiana has been completed as a joint project of the United States Geological Survey and the Indiana Geological Survey. Maps on a scale of 1 inch to the mile have been published for all counties. Because the sedimentary rocks in the state are essentially non-magnetic, variations in the magnetic character of the basement complex must be the major causes of anomalies shown on these aeromagnetic maps. The topography of the upper surface of the basement complex also affects the magnetic intensities at the surface, but this effect is insignificant in comparison with the effect of changes in magnetic susceptibility in the pre-Cambrian rocks. Because the sample representation is so sparse, the general aspect of the pre-Cambrian rock types is more important at this time in the interpretation of the aeromagnetic maps than the details of whether or not any particular sample contains magnetite.

The Indiana Geological Survey has completed a regional gravity survey of the entire state. The nature of the basement complex affects the strength of the gravitational field. Here again the genetic types into which the pre-Cambrian rocks fall are more meaningful than the density of any single sample.

The total thickness of the Paleozoic strata and glacial drift above the pre-Cambrian ranges from 3,333 to 3,895 feet in the test wells. The shallowest pre-Cambrian rocks encountered to date are in Jay County. Pre-Cambrian rocks identified in the drill cuttings are hornblende micrographic granite, dolomitic marble, siliceous argillite, augite andesite microporphyry, quartzite, and slate.

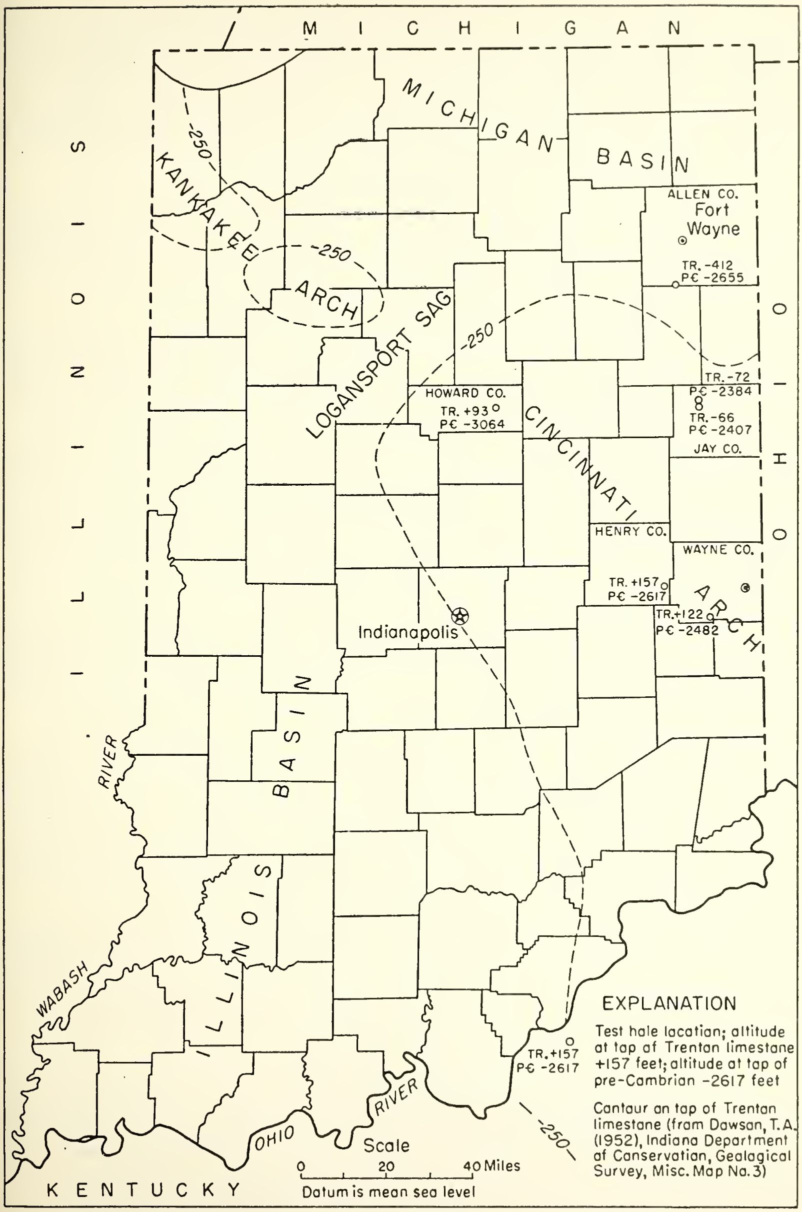


Fig. 1. Map showing pre-Cambrian test holes in Indiana.

Methods of Study

Small rock chips, ranging from 1 to 7 mm in diameter, were obtained from drill cuttings made available by the Petroleum Section of the Geological Survey, Indiana Department of Conservation. Mr. Edwin Hickam prepared sections about 0.03 mm thick from the rock chips. These thin sections, along with crushed fragments, were studied with the petrographic microscope and by X-ray diffraction and microchemical methods.

Pre-Cambrian Test Holes

Wayne County.—The Porter Gorden *et al.* No. 1 Doddridge was drilled in the NW¼NW¼NW¼ sec. 23, T. 15 N., R. 13 E. Chloritic hornblende micrographic granite was encountered from the depth of 3,439 feet to the total depth of 3,907 feet. Surface elevation was 957 feet.

Henry County.—The Ohio Oil Company No. 1 May was drilled in the SW¼SW¼SE¼ sec. 12, T. 16 N., R. 11 E. The same hornblende micrographic granite appeared at a depth of 3,649 feet and extended to the total depth of 3,670 feet. The reported surface elevation was 1,031 feet.

Jay County.—The Petroleum Development Company No. 1 Binegar was drilled in the NE¼NE¼NW¼ sec. 29, T. 24 N., R. 13 E. It encountered dolomitic marble at a depth of 3,351 feet and siliceous argillite from 3,374 feet to the total depth of 3,404 feet. More than one surface elevation was reported for this location. The elevation used for this report is 944 feet.

The Farm Bureau Oil Company No. 1 Binegar was drilled only one location north of the first deep well on the Binegar tract. The Farm Bureau well did not encounter marble at the top of the pre-Cambrian section but reached the siliceous argillite at 3,333 feet and continued in it to the total depth of 3,395 feet. Derrick floor elevation was 949 feet.

Howard County.—The Kokomo Gas and Fuel Company No. 1 Greentown was drilled in the SE¼SW¼NW¼ sec. 32, T. 24 N., R. 5 E. to a total depth of 3,996 feet. Alternating beds of yellow-brown to reddish-brown, iron-impregnated quartzite; blue-gray marble; pinkish-brown, siliceous argillite; and gray-green slate were encountered between depths of 3,895 and 3,996 feet. The surface elevation was 831 feet.

Allen County.—The Tecumseh Oil and Gas Company No. 1 Gibson was drilled in the NE¼SW¼SW¼ sec. 33, T. 29 N., R. 12 E. Dark, purplish-gray augite andesite microporphyry was encountered from 3,476 feet to the total depth of 3,517 feet. Surface elevation was 821 feet.

Paleozoic Strata

General statement.—The two wells drilled in Henry and Wayne Counties encountered the fossiliferous interbedded limestones and shales of the upper part of the Cincinnatian series (upper Ordovician) directly beneath the glacial drift. The other four wells encountered dolomite, dolomitic limestone or silty calcareous shale within the Niagaran series (middle Silurian). Westward from the Cincinnati Arch increasing thicknesses of Paleozoic strata lie above the pre-Cambrian rocks. The increase in thickness is caused mostly by the fact that Devonian, Mississippian and

Pennsylvanian rocks successively make their appearance toward the center of the Illinois Basin and partly to the fact that the Silurian and Devonian rocks thicken appreciably toward the center of the basin. Parts of the Mississippian section also thicken basinward.

Much the same situation prevails northward from the Cincinnati Arch into the Michigan Basin, although considerably less is known from subsurface data than in the case of the Illinois Basin. Northward from the Cincinnati Arch, Devonian and Mississippian rocks make their appearance beneath the glacial drift, as revealed by rather meager well data in the northern counties of the state. Northwestward from the Cincinnati Arch another structurally positive crest that has been called the Kankakee Arch causes Niagaran rocks to lie immediately beneath the drift in a belt that passes out of Indiana in the northwest corner of the state. Thus, except in the Logansport Sag, a narrow, structurally negative area centered in Carroll and Cass Counties (Fig. 1), Niagaran rocks underlie the glacial drift fairly continuously from Henry County and northern Wayne County northwestward to Lake Michigan. The best state-wide horizon for structural control has generally been considered to be the top of the Trenton limestone (middle Ordovician). Structural maps contoured on this horizon have been published within recent years by Harris and Esarey (6, fig. 4) and by Dawson (1).

The distribution of Upper Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian bedrock appears on the Geological Map of Indiana (9), and these strata will not be discussed in this paper. The Cambrian rocks and most of the Ordovician section are not exposed in Indiana and a resumé of their lithology and thickness as known from drilling will be given here. The Paleozoic succession in two of the pre-Cambrian test wells has been described by Esarey and Bieberman (2, p. 4-6).

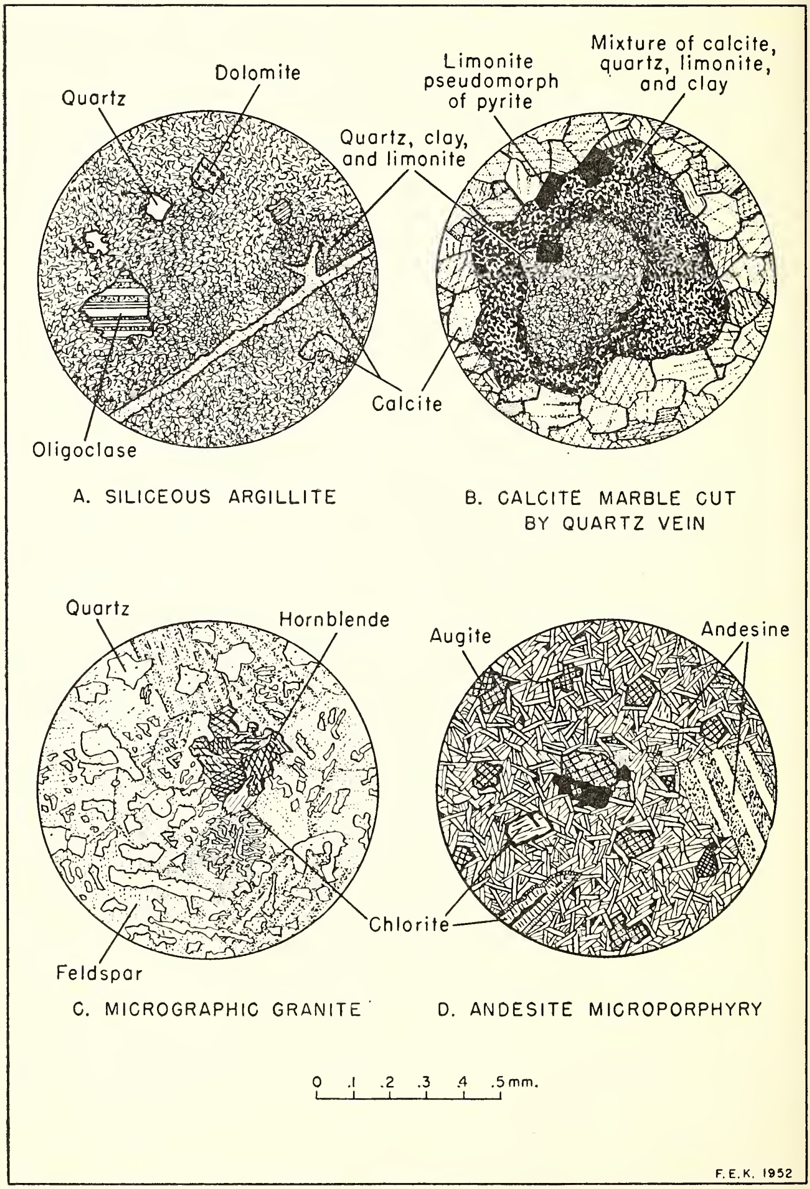
Cambrian rocks.—In all six of the test wells considered here, the pre-Cambrian rocks have been overlain by a thick, fairly pure, soft sandstone that has been correlated with the Mt. Simon sandstone, the basal formation of the Croixian Series (Upper Cambrian). The Mt. Simon has ranged in thickness from 237 to 406 feet in these wells. The sandstone is a mixture of white, amber, and pink grains that range from fine to coarse in texture, are angular to rounded, and poorly sorted. Cementation is generally poor and the sandstone is soft or only moderately firm in drilling.

The Mt. Simon is overlain by 530 to 735 feet of Upper Cambrian sediments that may contain equivalents of the Eau Claire and Dresbach sandstones. The lower part of this section consists of white and gray, fine- to coarse-grained, dolomitic, glauconitic sandstone. The large grains are rounded and frosted. The middle and upper parts consist of gray and pink, glauconitic, locally micaceous dolomite, mixed with minor amounts of gray-green and red shale.

In general the materials above this point are much more pure carbonate rock (mostly dolomite) than those below. This strong change in lithology appears to be the best place in the section to place the Cambrian-Ordovician contact.

PLATE 1

Kottlowski and Patton


Quartz
Dolomite
Limonite pseudomorph of pyrite
Mixture of calcite, quartz, limonite, and clay
Quartz, clay, and limonite
Calcite
Oligoclase
A. SILICEOUS ARGILLITE
B. CALCITE MARBLE CUT BY QUARTZ VEIN
Quartz
Hornblende
Augite
Andesine
Chlorite
Feldspar
C. MICROGRAPHIC GRANITE
D. ANDESITE MICROPORPHYRY
0 .1 .2 .3 .4 .5 mm.
F.E.K. 1952

Sketches of Thin Sections

Ordovician rocks.—A thick succession of rather pure dolomite occupies the Lower Ordovician interval. It is not readily divisible into formations, but it is roughly equivalent to the Prairie du Chien group (Lower Ordovician). In eastern Indiana the group is composed principally of white, tan, and light gray, crystalline dolomite that contains irregular thin beds of oolitic, chalky-white or blue chert. Fine quartz grains, glauconite, and disseminated pyrite are present but not abundant. The thickness of the group ranges between 724 and 1,261 feet in the wells reported here. The section thickens from north to south and from west to east.

The Chazy group (Lower Ordovician) is represented in the Wayne County well by an 8 foot zone that consists of round, frosted sand grains loosely cemented with dolomite. This zone is probably the St. Peter sandstone, although the St. Peter is not present as true sandstone in most of east-central Indiana. Round, frosted sand grains occur in beds of granular dolomite at about this horizon in many wells in the area.

Above the Chazy group lie the beds of the Mohawkian series (Middle Ordovician). The base of the series generally contains a 5 to 35 foot thickness of green, dolomitic shale in which round, frosted sand grains are locally plentiful. This green shale zone has been correlated with the Glenwood shale, the lowermost formation of the Black River group. The entire group ranges from 250 to 350 feet in thickness in the counties near the Ohio line. The portion above the Glenwood shale consists mostly of tan and brown, slightly dolomitic limestone that is dense to medium-grained and contains green, bentonitic shale in the upper part.

Above the Black River group lies the Trenton limestone, which is 150 to 200 feet thick in east-central Indiana. The formation consists mainly of tan to creamy-white, dense to crystalline, cherty limestone.

The Trenton limestone is directly overlain by dark, bluish, soft shales of the Eden group, succeeded by the fossiliferous, interbedded shale and limestone of the Maysville and Richmond groups. These three groups constitute the Cincinnatian series (Upper Ordovician).

Pre-Cambrian Rocks

Determination of the relative ages of the pre-Cambrian rocks studied from the six scattered drill holes can be only tentative. The rocks have undergone only mild metamorphism as is typical of the later pre-Cambrian rocks in the Great Lakes region. The quartzite in the Greentown well contains detrital fragments of hornblende micrographic granite similar to the granite in the May and Doddridge wells. Fragments of marble and siliceous argillite occur with quartzite in the upper section of the pre-Cambrian in the Greentown well, and greenish-gray slate is interbedded with the quartzite in the lower part of the hole. A chip of quartzite, composed of a simple mosaic of quartz (5, p. 67), occurs within the augite andesite in the Gibson well but is petrographically dissimilar to the quartzite in the Greentown well. The relative age of the augite andesite cannot be determined from the available data.

Marble.—The upper 20 feet of the pre-Cambrian in the Petroleum Development Corporation's Binegar well consists of medium-gray, recrystallized limestone or marble interbedded with and partly replaced by pinkish-brown dolomite. The carbonate grains are anhedral to subhedral and are arranged in decussate texture. The crystals average 0.16 mm in diameter, cleavages are indistinctly shown, and twinning lamellae are partly masked by numerous inclusions. A few lenses of extremely fine-grained calcite are composed of anhedral crystals that average 0.02 mm in diameter. Cement between the carbonate crystals and impurities within the crystals consist of limonite, siderite, illite (?), and cryptocrystalline silica. A few tiny, rounded, detrital grains of quartz are present. Limonite is pseudomorphic after cubes of pyrite.

Superimposed over the decussate texture of the carbonate grains are indefinite, discontinuous, parallel streaks in which limonite, illite (?), quartz, and minor chlorite are abundant. These bands may be relic lamination. Veins of cryptocrystalline silica cut the marble and are surrounded by irregular rings of silicified marble composed of tiny crystals of dark calcite, quartz, clay, and limonite. The larger limonite cubes of pyrite pseudomorphs are concentrated near these veins. Plate 1B shows a cross-section of a silica vein in marble.

Chips of similar dolomitic marble were obtained from the Greentown well. Laminae of quartzite occur in this marble.

Siliceous argillite.—The lower 30 feet of the pre-Cambrian in the Petroleum Development Corporation well and the entire 62 feet of pre-Cambrian in the Farm Bureau No. 1 Binegar are siliceous argillite that ranges in color through tan, pink, and light gray to nearly black. This rock may also be termed siliceous shale, siliceous siltstone, or sandy chert. Except for relatively large angular grains of quartz and feldspar, clastic texture is not present; the rock is a mesh of tiny quartz grains clouded by inclusions, cryptocrystalline silica, chlorite, illite (?), sericite, hematite, and carbonaceous matter. Calcite occurs as veinlets, as euhedral authigenic crystals, as angular detrital grains, and as a minor constituent of the cement. A few rhombs of dolomite are present. Angular grains of clear quartz and oligoclase, Ab_{84}, range from 0.1 to 0.2 mm in diameter. A few of these grains have hacksaw terminations which Pettijohn (10, p. 491) believed due to intrastratal solution. Several quartz grains show secondary enlargement. Relic hornblende crystals are laths composed of chlorite, limonite, calcite, and magnetite. Zircon occurs as rounded detrital grains.

Most of the crystals are 0.01 mm or less in diameter, as shown in Plate 1A. This is in the lower range of silt size. The larger detrital grains indicate a clastic origin for the rock. The bulk of the rock probably formed either by chert replacement of an argillaceous sandy limestone, or by deposition of fine clastic material which was cemented by silica plus impurities and was partly recrystallized during diagenesis.

In the Farm Bureau Oil Company's Binegar well, the middle layer of several chips from the upper part of the pre-Cambrian is a mixture of tiny calcite and quartz grains. One side of the chips is siliceous argillite, and the other side is fine-grained marble. Either the two types of rock are interlaminated or interbedded, or the marble is only partly replaced by silica and the metasomatism has proceeded along bedding planes.

The lower 13 feet of argillite in the Farm Bureau No. 1 Binegar is sufficiently calcareous to effervesce vigorously in dilute hydrochloric acid. However, the effervescence is brief, and appreciable loss in volume does not result. The residue consists of angular light blue-gray fragments that resemble chert.

A few chips of similar siliceous argillite which occur in the cuttings from the Greentown well may be from a pebble in the quartzite, or may be from strata interbedded with the quartzite. These chips contain silicified relics of fossils (algae?), and much carbonaceous matter.

Quartzite.—Reddish-brown to yellow-brown quartzite occurs throughout the 100 feet (?) of pre-Cambrian cut by the Greentown drill hole. The coloration is due to stain by limonite and hematite. The rock resembles granite if seen as small chips under a binocular microscope. In thin sections relatively large grains of quartz and feldspar are seen to be separated and cemented by small, rounded quartz grains. Secondary enlargement of the large crystals has, in places, engulfed the smaller grains. Two grain sizes predominate; the smaller consists of rounded to subangular quartz grains 0.01 to 0.03 mm in diameter, and the larger consists of oval to elliptical grains of granite, quartz, alkaline feldspars, chert, and hornblende partly altered to chlorite and limonite, averaging 0.4 mm by 0.25 mm in size. Skeleton crystals of iron oxides and chlorite occur as irregular prisms about 0.3 mm in diameter. The cement is chiefly crypto-crystalline silica and iron oxides, but also includes minor amounts of sericite and chlorite. Laminae and a partial cement of calcite occur.

Parts of the quartzite are entirely fine-grained. The grains average 0.05 mm in diameter and are heavily stained by limonite. Several chips, 2 mm in diameter, are entirely massive quartz crystals, cloudy with inclusions, stained by limonite, and fractured. The inclusions are in subparallel lines not parallel to bedding planes. Feldspars are cloudy, and many grains are almost completely altered to sericite and clay. Most of the quartzite chips are 90 per cent or more quartz, but several contain about 30 per cent orthoclase and albite (?). The grains of cryptocrystalline silica (chert?) contain much disseminated magnetite and limonite and resemble some varieties of flint. A 20 foot section near the base of the Greentown well has been described (8, p. 353) as "Igneous intrusion, diabase." The samples now available do not contain diabase. A speckled appearance that might be mistaken for microdiabasic texture is produced by a mixture (average grain diameter 0.02 mm) of clean quartz and quartz stained by fibrous iron oxides.

Near the bottom of the Greentown well the quartzite contains rounded grains, 1 to 2 mm in diameter, of the hornblende micrographic granite, and of perthite, resembling thin sections illustrated by Pettijohn (10, Pl. 24C and 24D). One quartz crystal clearly shows secondary growth. An inner rounded core, 0.4 mm in diameter, is cloudy quartz, outlined by a band, 0.05 mm thick, of small, rounded and angular quartz mixed with sericite and limonite. The core and band are surrounded by an irregular rim, 0.1 mm thick, of clear quartz.

Slate.—A few small chips of greenish-gray slate were identified from the lower part of the Greentown well. The rock is hard but splits easily along slaty cleavage into paper-thin flakes. In thin sections the slate is a felty mesh of chlorite, limonite, hematite, sericite, quartz, and clay minerals. Crystals are less than 0.01 mm in diameter except for irregular masses of hematite that are as much as 0.03 mm in diameter. Only a vague alignment of crystals was seen in the felty mesh.

Hornblende micrographic granite.—The granite is medium-grained, highly altered, hypidiomorphic-granular, and pink to the naked eye. Diameters average 1 to 5 mm. Most of the rock is a beautiful micrographic intergrowth of relatively clear quartz and highly altered feldspars (Pl. 1C); the feldspars are 75 per cent altered to kaolinite and sericite. Percentages from the Doddridge well are: quartz 33.3 per cent, orthoclase 43.3 per cent, microcline 10.4 per cent, albite 9.8 per cent, chlorite 1.5 per cent, and magnetite 1.7 per cent. This disregards the kaolinitization and sericitization. In this rock only skeleton crystals of the amphibole remain, altered to chlorite, chalcedony, and hematite. The deep weathering of the granite in the Doddridge well, which is altered for a depth of at least 400 feet, suggests that the alteration is due to hydrothermal solutions of the ore-bearing type or from a younger intrusion. Abundance of chlorite and sericite and lack of carbonates suggest hydrothermal solutions. Some of the chlorite even occurs as fibrous crystals along feldspar cleavages.

The granite from the May well is less altered, although the feldspars are mostly a felty mass of kaolinite and sericite. The quartz grains contain many tiny inclusions. Hornblende is pleochroic from aqua to greenish yellow-brown, with extinction at 22 degrees. The hornblende is altered to chlorite, iron oxides, magnetite, and chalcedony. Alteration begins along cleavages. Fibrous halos of chlorite form around pseudomorphs from hornblende. A few small crystals of fluorite, sphene, and zircon are present.

Augite andesite microporphyry.—The andesite occurs in the Tecumseh Oil and Gas No. 1 Gibson in Allen County. The rock is a felty mesh with ophitic texture of equigranular, colorless to pale green soda augite, laths of andesine, and scattered crystals of chlorite and iron oxides (Pl. 1D). The augite crystals average 1 mm x 1.5 mm in size and are partly altered to chlorite, iron oxides, and serpentine. Extinction from c to Z is as much as 70 degrees, which indicates aegirine-augite; the pale color of the crystals, however, is typical of augite rather than aegirine.

Andesine feldspar occurs in the groundmass as laths which average 0.16 mm to 0.04 mm in size. Phenocrysts of andesine average 0.3 mm by 0.7 mm in size and are mostly altered to clay minerals and some sericite. The small laths of andesine lose their form when altered. The andesine is Ab_{49}, which is very close to labradorite. Chlorite and antigorite (?) serpentine occur in flamboyant radial aggregates associated with cubes of magnetite and coatings of limonite and hematite. A few crystals of secondary quartz and calcite occur in the interstices. The andesite is cut by veinlets of calcite, cryptocrystalline silica, antigorite, and chlorite, bordered by rims of iron oxides.

The upper part of the andesite is greatly altered, probably due to weathering prior to deposition of the Cambrian strata. The weathered rock is heavily stained by iron oxides. Only a few relic cores of augite remain surrounded by chlorite, hematite, and chalcedony. Banded fibrous veinlets and pods of chlorite occur with cores of red hematite. The ophitic texture is lost in a structureless mesh of secondary minerals.

Correlations

The nearest outcrops of pre-Cambrian rocks are in northern Michigan, Wisconsin, and Missouri. The pre-Cambrian rocks examined from six deep test wells in northern and western Illinois were described by Grogan (3). Granophyre (7) from the Eastern-Mumford drill hole in Pike County, Illinois, vaguely resembles the hornblende micrographic granite but lacks hornblende or any other primary mafic minerals. Several chips of the quartzite from the Greentown test well partly resemble the rhyolite porphyry from the Campbell test well in Pike County, Illinois, except that the clastic origin of the Greentown quartzite appears to be fairly certain. Secondary enlargement of quartz and feldspar crystals are common in the rhyolite porphyry in Missouri (11) but the groundmass of this rock has a felty texture in contrast to the clastic texture of the quartzite. That only igneous rocks were encountered in the six Illinois drill holes is surprising in view of the thick sections of metasedimentary rocks that crop out in Wisconsin, Minnesota, and Michigan (12, 4).

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Geologic Characteristics of Indiana Streams

PRESTON MCGRAIN[1] and MAX MITCHELL[2]

Introduction

Some precipitation while passing through the water cycle reaches streams that flow over the surface of the land. Their importance as sources of water supply for municipalities, industries, and agriculture is well known. The amount of water available from surface supplies varies greatly. These variations are dependent upon two groups of factors. One group of factors is based upon the geologic and topographic conditions of the drainage basin; the other group includes weather and climate. It is the former group with which this paper is concerned.

Surface waters in their courses across Indiana encounter a variety of geological conditions. A steep slope of solid rock will yield promptly nearly 100 per cent of the rainfall. A sandy plain covered with vegetation will slowly yield a small percentage of rainfall directly, in extreme instances approaching zero. The character of the earth materials and geologic processes not only affect the topographic conditions of a region but also are factors affecting natural drainage, runoff, and other hydrologic characteristics. In order to properly interpret and appraise the characteristics of the streams bearing these waters, a knowledge of the terrain and the earth materials present within each drainage area is imperative. Figure 1 shows the major drainage divisions within the State.

The stream flow throughout most of Indiana has considerable regulation by the presence of the great blanket of glacial drift over much of the State. The glacial drift, where porous, acts as a storage basin for ground water. Many of the valleys of the rivers draining away from the glaciated area are deeply filled with sand and gravel. These valleys also retain large volumes of water. The ground water released from these areas is the base flow of these streams and is the total flow during dry seasons. The area north of the Wabash River still largely retains the original forms following continental glaciation. The presence of many lakes, marshes, and shallow basins tends to regulate the flow of streams in that area. The middle portion of Indiana is largely a great till plain of low relief. The type of glacial material found here is not as useful in retaining water as that found in the morainic areas and along the discharge routes of melt waters. The greatest diversity of both relief and rock types are found in the unglaciated portion of southern Indiana. These variations have a marked effect upon the characteristics of the smaller streams.

Major Drainage Areas

WABASH. The Wabash drainage basin, excluding the White and Patoka rivers, lies almost entirely in glaciated areas. The regional direction of the main tributaries of the Wabash River has been determined to a large extent by the presence of the crescent-shaped terminal moraines

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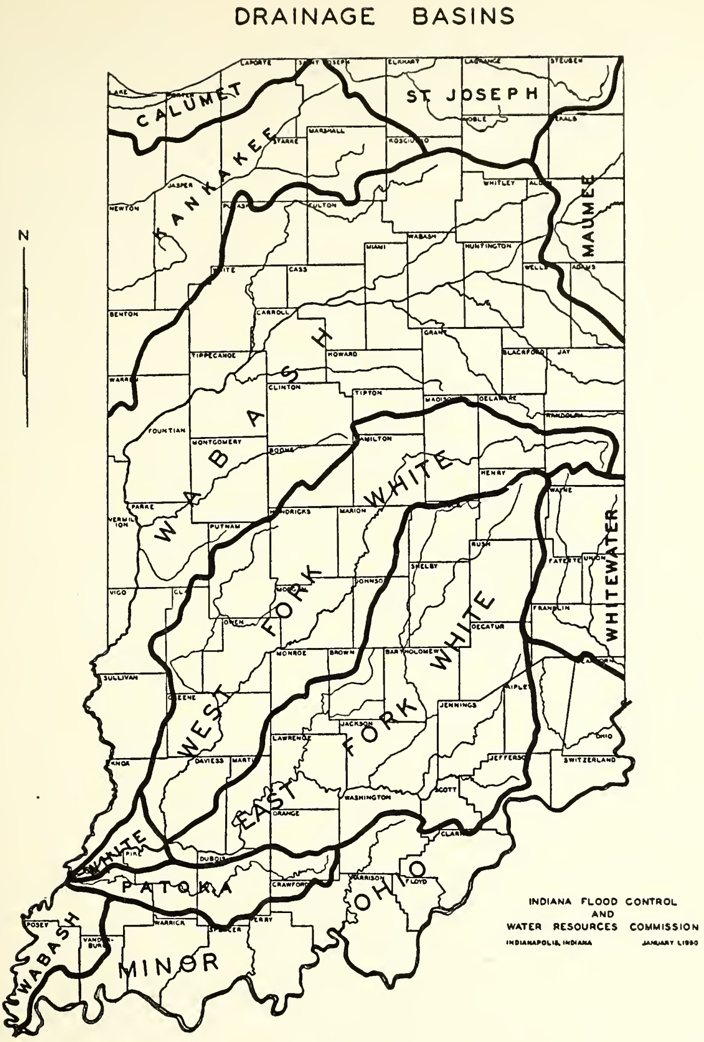
[2] Indiana Flood Control and Water Resources Commission, Indianapolis, Ind.



INDIANA FLOOD CONTROL
AND
WATER RESOURCES COMMISSION
INDIANAPOLIS, INDIANA JANUARY 1950

Figure 1

in the headwater portions. The valleys of the Wabash, Salamonie, Mississinewa, Eel, and Tippecanoe rivers and the valleys of many of the other streams were carved out chiefly in glacial times and have suffered little alteration since that time. Farther south the glacial plain is older. Considerable dissection of the glacial plain has taken place along the Wabash River and in the area between Lafayette and Terre Haute. Tributaries such as Big Pine, Little Vermilion, Sugar, and Raccoon creeks flow through rocky gorges.

The Wabash drainage basin, as defined above, encompasses 11,965 square miles in Indiana. Because of its size several types of geology and topography are expressed. That part of the basin lying north of a line from Columbia City to Monticello stores much water in the outwash plains and gravel-filled valleys. Elsewhere surficial deposits are largely a clay till which will absorb relatively little precipitation, even though the relief is not great.

EAST FORK OF WHITE. A great diversity of geologic and topographic conditions exists in the drainage basin of the East Fork of White River. The headwaters of this 5,680 square mile area rise in the glacial till plain area of Henry County at elevations of greater than 1,100 feet. The main streams and tributaries flow in a west and southwest direction. In the southeastern part of the East Fork of White drainage basin the topographic condition reflects the structural attitude of the underlying resistant rocks. Although the whole area has been subjected to glaciation, the surface slope corresponds very closely to the slope of the rock strata. The streams rising in the southeastern part of the basin are relatively swift and flow at or near bedrock surfaces except locally.

Between west-central Jackson County and the western edge of Martin County, East Fork of White River crosses unglaciated Indiana. Here the greatest local relief in the basin occurs. This large stream system enters the unglaciated area through a notch in the Knobstone escarpment in western Jackson County. The Knobs area is characterized by high, rugged hills, deeply dissected valleys, great local relief, and impervious rock formations. Runoff is necessarily rapid. Salt Creek, the largest tributary to enter East Fork of White in the unglaciated region, lies almost entirely in this rugged area.

On westward in Lawrence and Orange counties the basin occupies a portion of a limestone region which is characterized by subterranean drainage features. Drainage is largely through sinkholes. Surface tributaries in the limestone area are rare, but where present are usually short. The headwaters' portion of Lost River is situated here.

East Fork of White River follows a deeply entrenched, meandering valley south and west across Martin County. High and low hills, V-shaped and flat-bottomed valleys, bluffs, and sandstone-capped ridges, and almost flat table lands produce a variety of features throughout this part of the drainage basin. From the Martin-Daviess county line to the confluence with the west fork, East Fork of White River flows through a region which can best be described as hilly to rolling. The topography is nowhere as rugged as the Martin County area and immediate local relief rarely exceeds 100 feet. The relief becomes more subdued toward the confluence of the two forks of White River, and earth materials more capable of retarding surface runoff.

WEST FORK OF WHITE. Like its counterpart to the east, West Fork of White River drainage basin contains diversified geology and topography. The headwaters of this stream lie within a few miles of the headwaters of East Fork of White and Whitewater rivers. The watershed boundary between these drainage systems contains the highest elevations in the State.

The entire length of West Fork of White River and most of its drainage basin, some 5,430 square miles, lies within the glaciated portion of Indiana. Vast quantities of water are stored in the sands and gravels that fill the valley from above Indianapolis to its junction with the east fork and thus serve to help regulate the stream during periods of low flow.

From the headwaters to northeastern Morgan County, West Fork of White River flows across the glacial plain. Bedrock is exposed occasionally along the valley but glacial materials predominate. In southern Morgan County the stream crosses the northern extremity of the exposed Knobs area. Steep, rocky slopes are present along the valley but the uplands are capped with glacial drift and are generally flat. Bean Blossom Creek, which joins West Fork of White River in the extreme northwestern corner of Monroe County, has most of its drainage area in the "Knobstone" region. The low flow of this creek during summer months and its high rate of discharge during periods of precipitation reflect the inability of the rocks to retain or store water.

Only a small part of West Fork's drainage area lies in the sinkhole area of southern Indiana. The limestone plain which it crosses has been modified in part by glacial deposits and subterranean drainage is relatively insignificant. That portion in Owen and northern Greene counties is as diversified and rugged as any within the drainage basin. Massive sandstones cap hills and ridges, and form rugged bluffs and steep slopes. However, from Worthington in Greene County to the confluence with the east fork the topography is more subdued, becoming rolling to almost flat.

PATOKA. The geologic and topographic conditions present in the 860 square miles making up the Patoka drainage basin fall under two general types. That area between the headwaters in Crawford and Orange counties and Jasper in Dubois County is typical of the Crawford upland physiographic region of Indiana. Rugged hills, ridges, and bluffs, deeply dissected valleys, and considerable local relief are present throughout this area of Chester and Pottsville outcrop. Most of the tributaries are short and steep, and runoff is rapid. From Jasper westward to Wabash River the topography is gently rolling to almost flat. Here, too, the tributary streams are short but their gradients are not nearly so steep. The local relief decreases progressively to the west as Pennsylvanian shales predominate. Many of the frequent floods along this stream are the direct result of the physiographic conditions found within the drainage basin.

MINOR OHIO. The greatest diversity of relief and rock types in Indiana is found in the Minor Ohio River drainage area, an area of some 4,040 square miles. The region bordering the Ohio River, though the portion upstream from Jeffersonville was subjected to glaciation, represents the severest relief in the entire State. The severity, however, is greatly reduced downstream from Grandview in Spencer County.

Most of the streams are short and relatively steep, and flow through rock-walled valleys. Blue River, which drains portions of Washington, Harrison, and Crawford counties, has the largest drainage area of any streams in the Minor Ohio drainage basin. It lies almost wholly within the cavernous limestone belt of southern Indiana and its tributary drainage is largely underground. The subterranean drainage peculiarities of this stream directly affect the characteristics of its runoff pattern.

WHITEWATER. The Whitewater River drainage basin lies entirely in the glaciated area. Whitewater River rises by two main branches in southern Randolph and Wayne counties. The two branches join at Brookville from which it flows southeast to the junction with the Miami River at Valley Junction, Ohio. The drainage basin, including adjacent minor Miami River drainage, encompasses 1,355 square miles. Is it in an upland area which reaches elevations of over 1,000 feet. The main streams have trenched this upland from 200 to 300 feet below the general upland surface, though much of the upland surface is still preserved. Areas of upland near the headwaters of the streams are notably flat and often quite extensive. Most of the tributary streams are short and the fall from the upland headwaters is relatively great. Along the main streams the slopes are most frequently quite steep, though bluffs are rare.

The bedrock formations are largely the interbedded limestones and shales of Cincinnatian age. The lower courses of the two main valleys contain thick deposits of sand and gravel as terrace deposits and valley fill. The inability of the rock formations to store water precludes the development of surface water supplies on the smaller streams except through impounding.

MAUMEE. The Maumee drainage basin, covering 1,285 square miles, lies entirely within the glaciated portion of Indiana. However, a variety of conditions are present. The St. Joe River rises in the rolling lake and moraine district north of Fort Wayne. The St. Mary's River rises in the nearly flat glacial till plain region of Ohio and flows northwest to Fort Wayne where it joins the St. Joe to form the Maumee. Lobate moraines separate the St. Joe and St. Mary's rivers from the Maumee and from the headwaters of the upper Wabash system. In Allen County the Maumee River flows across a flat, featureless, lake plain which covers about 120 square miles. The plain has an elevation of about 750 feet above sea level; the channel through which the Maumee flows has been cut 25 to 40 feet below the lake plain. In spite of their glacial origin and low relief the earth materials are of low permeability.

KANKAKEE. The greater part of the Kankakee drainage basin is characterized by a broad plain covered with a thin deposit of somewhat ridged sand. The most prominent ridges are 35 to 40 feet in height, but the majority are less than 20 feet, and many are only 5 or 10 feet. Dunes also are common but nowhere approach the size of those along Lake Michigan. A morainic ridge, which passes through the middle of Newton and Jasper counties, separates the sandy plain along the Kankakee River from the sandy plain along the Iroquois River. This moraine is narrow and has a rolling or hummocky topography. The extremely flat terrain and the presence of sand and muck soils permits great storage of water and slow runoff. However, the presence of many artificial drains, both open ditch and tile, allows surface runoff to reach the streams in a shorter time than it would otherwise.

CALUMET. The 615 square mile area described here includes both the watershed of the Calumet River system and minor Lake Michigan drainage. Two distinct geologic conditions are present here. The area just south of the tip of Lake Michigan was once covered by lake waters and is now represented as a lake plain. It is marked by a number of low sand ridges which extend parallel to Lake Michigan. The outer margin of the plain is somewhat trenched by Deep River and its tributaries in the vicinity of Hobart. East and northeast of Gary and adjacent to the lake occurs a belt of duns. Mt. Tom, the highest of these massive dunes, rises over 190 feet above the surface of Lake Michigan. The altitude of the lake plain is below 640 feet. Lake Michigan normally has an altitude of about 580 feet.

Beyond the lake plain is the Valparaiso moraine, a massive moraine curving about the head of Lake Michigan. It is composed of ridges, knolls, sags, and basins. The moraine rises abruptly above the lake plain, and within two miles has risen 150 feet. Its highest knolls are approximately 300 feet above Lake Michigan and approximately 10 miles distant. Its basins contain a number of small lakes. The Valparaiso moraine is the divide between the St. Lawrence and the Mississippi drainage basins in the northern part of Indiana.

ST. JOSEPH. The St. Joseph drainage basin, an area of 1,645 square miles, is situated in a region of variable topography. The surface of this area is composed of the younger drift of the last glacial epoch to reach Indiana and contains some of the thickest deposits of glacial drift known in the State. Porous sand and gravel deposits are abundant and are important factors in affecting the runoff characteristics of the surface waters. An outwash gravel plain, one of several gravel plains in the drainage basin, stretches southeast in St. Joseph County from the outer margin of the Valparaiso moraine.

Elkhart, Little Elkhart, and Pigeon rivers, important tributary streams, have their headwaters in the lake and moraine region of northeastern Indiana. Massive, rugged moraines and hundreds of lakes and marshes characterize this latter area and control runoff conditions. The highest knolls and ridges are in Steuben County where elevations of 1,200 feet are present.

Conclusions

The geology and physiography of a drainage basin, that is, the character of the earth materials, the steepness and nature of the land forms, and gradients, have striking effects upon the streams of Indiana. These factors vary from one area to another. However, they are most pronounced in the watersheds of the smaller streams. In the larger rivers the effects of several types of geology and topography tone down small area characteristics, or successively change characteristics as they pass from one section to another.

The physiographic classifications provide a key to the general topography and character of the land surface and the hydrologic conditions in the area. The glacial deposits are relatively more important than sandstones, limestones, and shales in a hydrologic sense, for the character of the surficial material determines in a large part the rainfall-runoff relation in Indiana. As the character of glacial drift may range from impermeable till to highly permeable gravel in a short distance, the glacial geology as well as bedrock geology requires intensive study.

Cities with a Population Decline in Southwestern Indiana 1940-1950

THOMAS FRANK BARTON, Indiana University

Fifteen Indiana cities experienced a decline in population during the decade of 1940-1950. Eleven of these 15 are located in southwestern Indiana within a 70-mile radius of Vincennes. Of the 17 cities showing a growth of less than five per cent during the past decade, nine are located in the same general area. Although there is something exhilarating about rapidly growing cities and something depressing about declining ones, whether permanent or for a brief decade, both types offer challenging research problems. The core of this paper is confined to a discussion of "Cities with a Population Decline in Southwestern Indiana." The writer hopes to continue this small study based on library research and brief reconnaissance field work later by extensive field research.

Amount of Decline

The amount of population decline in the 10 cities of southwestern Indiana varies from 1.3 per cent in Petersburg to over 14 per cent in Jasonville or one-seventh of the latter's population. The following table shows the percentage of decline for each city (See Table I).

The decrease in population of French Lick, a resort city in Orange County, was large enough to take it out of the city class. Since it no longer has a population of 2,000, it will be excluded from further detailed treatment in this paper.

TABLE I

Loss of Population in Ten Southwestern Indiana Cities*

City	*Loss in Numbers*	*Decline in Per Cent*
Petersburg	40	1.3
Princeton	113	1.5
Mitchell	148	4.4
Linton	290	4.6
French Lick	96	4.7
Bloomfield	184	8.1
Clinton	630	8.9
Cannelton	213	9.5
West Terre Haute	373	9.9
Bicknell	538	10.5
Jasonville	481	14.1

* Statistics in this table taken from mimeographed manuscript of the Indiana Economic Council entitled "Comparative Rate of Growth of Small, Medium-sized and Larger Cities in Indiana."

Since more and more people employed in the city live in individual and apartment dwellings in the country, we should consider the population trend of the townships in which the cities are located. Six of the 10 cities in Table I are in townships which show a population decline each decade for the last 30 years. Three of the remaining four, Cannelton, Princeton and West Terre Haute, are located in townships which continue to show increases in population decade by decade. Cannelton is in Troy Township in which two other urban areas are located. Although Princeton had a population decrease of 113 people, Patoka Township, in which Princeton is located, gained 90 people. Sugar Creek Township, in which West Terre Haute is located, gained in population every decade except the 1920's. Although West Terre Haute lost 372 people, Sugar Creek Township gained 491, resulting in a net gain for the city and township of 119 people. Marion Township in which Mitchell is located gained in population until the last decade.

But it is obvious that the city to country movement cannot account for the population decline of our cities in the southwestern part of the state.

The ten cities under consideration here are primary trading areas within their counties; consequently one should consider the population trend of the eight counties in which they are located.

During the 1940's six of these eight counties showed a population loss. Three of the cities, Bloomfield, Jasonville and Linton, are in Greene County. Greene County's population declined from 31,330 to 27,886—a loss of nearly 11 per cent. Pike County in which Petersburg is situated showed a decline of 12 per cent. During this same decade Vermillion County, in which Clinton is found, declined over nine per cent and Perry County with the city of Cannelton declined two per cent. Lawrence County with the city of Mitchell and Knox County with Bicknell had minor losses of less than two per cent.

Moreover, the county population loss exceeded that of the declining cities in each of the six counties, namely Greene, Pike, Vermillion, Perry,

TABLE II

Population Trends in Eight Counties

County	*1950*	*1940*	*Change in Number*	*Change in Per Cent*
Pike	14,995	17,045	—2,050	—12
Greene	27,886	31,330	—3,444	—11
Vermillion	19,723	21,787	—2,064	—9
Perry	17,367	17,770	—403	—2
Lawrence	34,346	35,045	—699	less than 2 loss
Knox	43,415	43,973	—558	less than 2 loss
Gibson	30,720	30,709	11	nil
Vigo	105,160	99,709	5,451	+5

Lawrence and Knox (See Table II). Of the eight counties under consideration only two showed population increases, and in one of these two the increase was practically nil. Gibson County in which Princeton is located had an increase of only 11 people. Vigo County in which West Terre Haute is located increased five per cent (See Table II). However, we must remember that Terre Haute is the primary city in Vigo County.

Consequently we may safely make the generalization that not only are the ten cities declining in population but that the townships and counties in which they are located are also losing population or remaining nearly stagnant.

Function of Cities

The question of why these cities have decline still remains unanswered. It is a truism that cities grow as they perform services for people. A historical geographic perspective should prove useful in an evaluation of the present situation.

Cities in southwestern Indiana developed as trade, mining, political, manufacturing and transportation centers. The first two functions, trade for an agricultural area and furnishing supplies for the needs of miners and quarry workers have been major factors in the growth of cities in this part of the state. The agricultural and mining employment and prosperity of this area is reflected in its cities. The mining industry is the more unstable of these two.

Relative Location to Coal

All of the ten cities under consideration are located within the boundaries of the coal fields in southwestern Indiana. All of them have benefited either directly or indirectly by the coal mining industry and some are known as coal mining cities although none are restricted to a single function of providing the needs for miners.

Not only are these cities located within the coal fields but some are within or on the edge of the concentrated areas of strip mining. For example, Jasonville, Linton, Bicknell, Clinton and Petersburg are surrounded by strip mines.

During recent decades the employment of coal miners in southwestern Indiana has decreased. The industry pays better wages but fewer miners are needed. Within this general area some miners have had to turn to other forms of employment. Others commute long distances daily as much as 100 miles a day or more. Naturally some move closer to their new place of employment. Mining villages have lost half of their population in recent decades.

This decreased employment has its influence on both the villages and cities where miners live and upon the principal trade center of the county. For example, the decline of population in Jasonville and Linton does influence the prosperity of Bloomfield, the county seat and primary trade center of the county.

Cities and Villages in Greene and Sullivan Counties

One of the largest areas of strip mining concentration is astride the Greene-Sullivan County boundary. Within these two counties there are four cities and nine villages (A village refers to incorporated settlements with less than 2,000 inhabitants.) for which census statistics are available. Detailed information may be obtained by studying Table III. Several significant generalizations may be made from the statistical information in this table.

With the exception of Sullivan, the county seat, and Farmersburg the population trend is downward for cities, villages and counties. Population has been declining in Greene and Sullivan counties for the last forty years. Nine of these 14 cities and villages reached their peak in 1910 or 1920. Consequently a population decline has been characteristic of these settlements for the last 30 years (See Table III).

TABLE III

Consecutive Decades of Population Decline of Cities, Villages and the County in Greene and Sullivan Counties

County City or Village	Population Lost During Decade of					Decade of Highest Population
	1940	1930	1920	1910	1900	
Greene County	X	X	X	X		1910
Bloomfield	X	X				1930
Jasonville	X	X	X			1920
Linton	X					1940
Worthington	X					1920
Newberry	X	X	X	*		1920
Switz City	X	X	*			1930
Lyons	X	X	X	X	*	1910
Sullivan County	X	X	X	X		1910
Dugger	X		X		*	1920
Farmersburg			X			1920
Hymera	X		X		*	1920
Shelburn	X		X	X		1910
Sullivan		X				1950
Merom	X		X	X		1910
Carlisle	X		X			1920

* Indicates unavailable data

Agricultural Trade Areas

With the possible exception of Princeton all of these cities are located in rather poor agricultural areas. Yields are below average for the state and the farm population has been decreasing.

For example, the eastern half of Bloomfield's trade territory is on the Crawford Upland. From the standpoint of cultivated agriculture, the Crawford Upland is the most rugged and one of the least desirable physiographic regions in southern Indiana. The western half of Bloomfield's trade territory is on the Wabash Lowland. In this area strip mining has been carried on extensively, taking large areas out of cultivation.

Cannelton is another city located near the edge of the Crawford Upland. It is an Ohio River city with its trade territory to the north and east, and confined chiefly to the Crawford Upland. Of course it is also handicapped by having to compete with Tell City only a few miles away.

Mitchell is located on the Mitchell Plain, a region of karst topography and poor cultivated agriculture.

All three of these cities—Bloomfield, Cannelton and Mitchell—are located in the unglaciated section of the state called the South Central General Farming region. This area can be characterized as one with 1. much of the land in slope, 2. poor soils highly leached and much eroded and 3. small unproductive farms. "No other area in Indiana has as large a proportion of self-sufficing farms." (3). During the pioneer period farmers practiced lumbering to help supplement their crop income. But forests as well as soil have been depleted by "mining" and conservation practices are not widespread or long practiced.

Much of the land can be more productively used for pasture and forests. However, pastures and forests are extensive uses of land and do not help support heavy rural population which may contribute to a prosperous trade area for the city. Unless the better land can be used more intensively such as for dairying, poultry and trucking and thus employ more people, the rural population of the city trade areas will continue to decline.

Bicknell, Clinton, Jasonville, Linton, Petersburg, Princeton and Shelburn are located on the Wabash Lowland and in a type of farming called the Southwestern Corn, Wheat and Truck Area. The first four cities as treated under Relative Location to Coal are surrounded by strip coal mining areas. After stripping, the land is too rough for cultivation, and as yet no date has been predicted as to when lumber operations may start on the "reforested" spoil banks. Like the Crawford Upland, large areas of land could be more profitably used to grow trees, hay or pastures rather than cultivated crops.

Modern mechanized farming like modern mechanized mining reduces employment. For example, the farming area in the vicinity of Lyons, in Greene County, has a reputation of being good farm country. Yet, Washington Township in which Lyons is located reached a peak population of 2,404 in 1900 and has declined in population during every decade since that time. Today, a man with a tractor, combine and other modern machinery can cultivate as much land as four farmers could fifty years ago, and perhaps has only one or two children compared with 15 to 20 of the former four families. Yet in the early years the cities of agricultural areas grew in part by supplying the needs and wants of an expanding rural population.

County Seat Trade Centers

In recent decades most of the county seats of the less urbanized counties in Indiana have become the primary trade centers. In spite of this trend, three of the 10 cities with declining populations are the county seat and the largest city in the country. These three are Petersburg, Princeton and Bloomfield.

Manufacturing

Industrial employment is the major support of most cities in the United States today. Although there are some local industries in the cities covered in this paper, these cannot be characterized as industrial cities—they are rather farming and mining centers. The population of some cities in southwestern Indiana has been maintained or increased because of the establishment of new industry and/or the expansion of older factories. Bedford is an example in which the people are stressing the manufacturing function of a city and thereby maintaining its population.

Princeton and Petersburg in adjacent counties are a contrast in the importance of manufacturing. During the last decade both of these had a similar population decline. However, Patoka Township in which Princeton is located gained 90 people in the last decade, whereas Washington Township where Petersburg is situated reached its peak of population in 1940. New and expanding industries in Princeton provide more employment for workers than is true in Petersburg. More people commute to work in Evansville from Petersburg than they do from Princeton.

The important question is, "Will enough new factories be established and old ones expanded in order to provide sufficient employment so that the declining trend in population of these cities and their townships will be reversed during this and future decades?" (1).

Associated Cities

Associated with the 10 cities which we have under consideration are others having practically no growth in the last decade. Seventeen or over one-tenth of the cities in the state showed practically no growth (0-4.99 per cent increase) and this group might be characterized as stagnant (2). Eight of the 17 are in southwestern Indiana, namely Bedford, Brazil, Jasper, Loogootee, Rockport, Spencer, Terre Haute and Vincennes.

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Some Geographical Factors in a Quarter Century of Indiana Harvests 1926-50

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This paper discusses how certain geographical factors directed, hindered or helped Indiana agriculture during the period 1926-50.

Soil, geomatical position and other "attributes of place" will be touched upon. The two aspects to receive most attention are weather and economic geography.

Weather is so prominent because it early became an objective. There is also another reason: Weather records and crop reports supply basic cause-and-effect data.

Economic geography is the confluence of two major activities of the region, agriculture and commerce. Further, Indiana farms now produce more raw materials for industry than they did a quarter century ago.

Graphs of harvested acreage will be used to isolate trends in the major crops. Topical graphs will further pinpoint and develop the data.

The top line of Figure 1 represents the total acres of field crops harvested in each year of the quarter century 1926 through 1950. Tree fruits and small fruits are excluded.

Hoosier farmers sometimes decided not to plant a portion of their lands. At the low points in the graph, potential cropland has been idle or in pasture. The spread between the extremes equals about 10% of the potential cropland.

The lower line is the corresponding data for corn. On the average, four out of ten acres of Indiana cropland were in corn. In general, there is a direct correlation between the two lines. Since 1941, the spread between the curves has widened. Corn is still king, but he is sharing his throne with another crop.

Figure 2 shows the acreage trends in the harvests of four other major Indiana crops. The curves have been slightly smoothed. It is interesting to note the relative position of each to the 2-million-acre line.

Wheat acreage had its major swings. The difference between the 1937 peak and the 1943 valley was close to 1 million acres. The notch at 1928 is due to winter-kill the preceding winter.

Oats declined until 1939. Since 1943, it has fairly well levelled out at about two-thirds of a million acres less than in the late 1920's.

Soybeans were unimportant until the end of the depression. The steady upward climb of soybean acreage reached a plateau in 1943. From that date until 1950, the annual average was just under 1½ million acres. As you may have guessed, soybeans now share the crop throne with corn.

Hay acreage has shown the least variation of any major crop. The slight downward trend after 1940 was due to increased production per acre.

Rye, barley and buckwheat are so minor that we will quickly dispose of them. From 1926 to 1940, these three grains together averaged about one-eighth of the wheat acreage. Thereafter they declined 50 per cent.

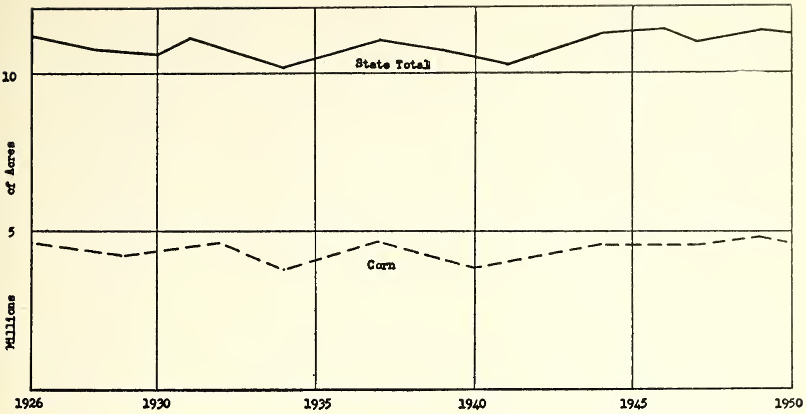


Fig. 1. Indiana harvests, 1926-50, excluding fruits.

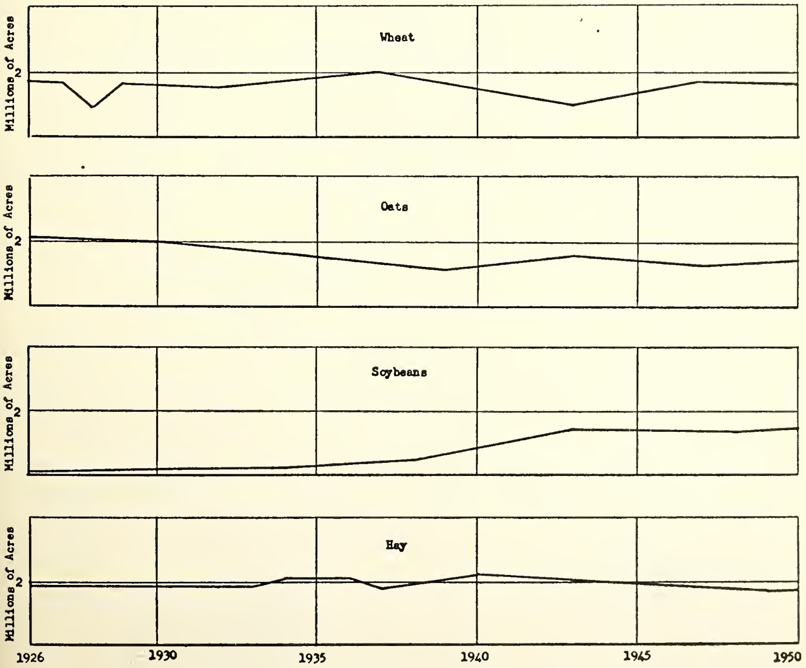


Fig. 2. Four major crops of Indiana harvests, 1926-50.

Let us now turn from the dominant field crops of the state to the special crops. Until we see them catalogued, few of us realize the scope of these special crops.

For our quick survey, we shall subdivide them into two groups. The first group covers crops grown for processing, such as tomatoes, sweet corn, cucumbers for pickles, mint and sorghum. The second group consists of tobacco, popcorn, market garden vegetables and melon crops.

Indiana's special crops are largely confined to certain sections of the state by latitude, lay of the land, type of soil, or the presence of processing or marketing facilities. On an area basis, only 2% to 3% of the state cropland is devoted to all these special crops. Because they are a form of intensive agriculture, such crops have recently produced from one-seventh to one-fifth of the total cash-crop revenue. Those special crops which are processed within the state add diversity and stability to the state's industry.

The dominant special crop for processing is tomatoes (Figure 3), which generally accounts for nearly one-third of the special crop acreage. Sweetcorn is next in importance. We have included mint with the processing crops because it has to be distilled.

Peak years for corn and tomato acreage result in an increased ratio within the normal supply area. The perimeter of the supply area may also expand as the processors' price rises.

Hauling, now done almost exclusively by motor trucks, is rapid, cheap and easy where geographic barriers are few and minor as in Indiana.

The mucklands of northern Indiana have a natural monopoly in the growing of spearmint and peppermint. Mint crops are subject to an unusual hazard of Indiana weather, wind. Plants flattened by wind are difficult to harvest. The oil yield is reduced, too, when that volatile substance escapes through breaks in the leaves.

Sorghum is of little commercial importance. In recent years, the reason has been economic. Hand labor is required to strip the leaves and cut the stalks.

On Figure 4 is the second division of special crops. Perhaps you are surprised at the potato acreage Indiana once maintained. Subsidy payments and changing food habits are responsible for the drop.

In years of state-wide drought, truck crops in the spongy lacustrine soils of the northern districts have suffered little. Conversely, excessive spring rainfall and subnormal temperatures delay plantings in such soils. With the advent of seasonable weather, their crops grow profusely. If the frost date is normal or later, production is high despite the slow start.

Capitalizing on latitude and soil, certain sections of southern and southwestern Indiana grow melons. The light soils desirable for this culture warm up rapidly as summer insolation increases. Drought is a major peril. Good markets await in metropolitan areas only hours away by modern transportation.

In both a geographic and an economic sense, a considerable portion of Indiana's tobacco land is marginal. Started by hotbed methods, tobacco is very sensitive to extremes of weather for several days after transplanting.

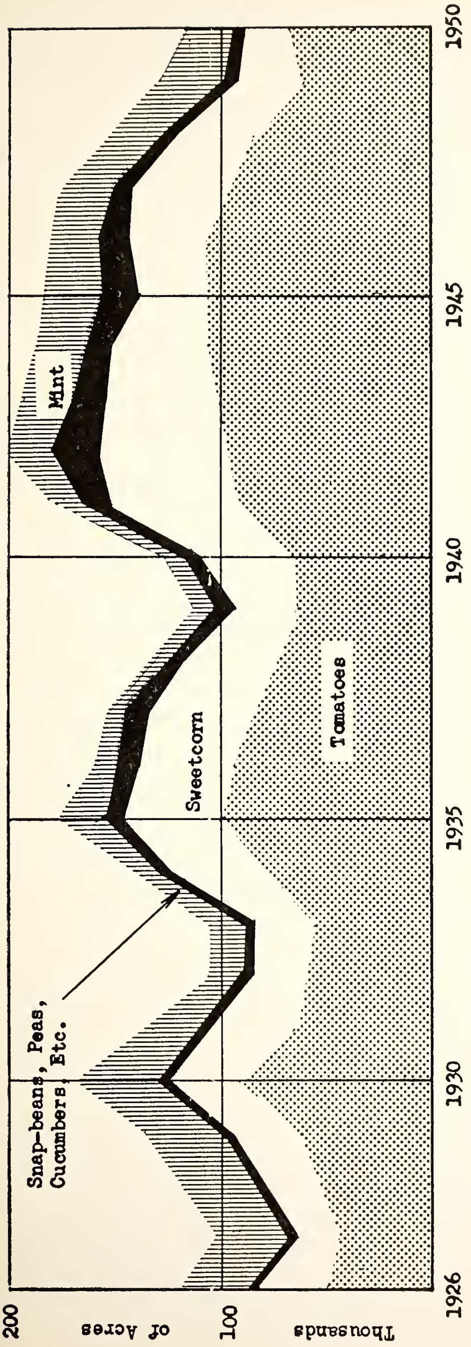


Fig. 3. Special crops for processing.

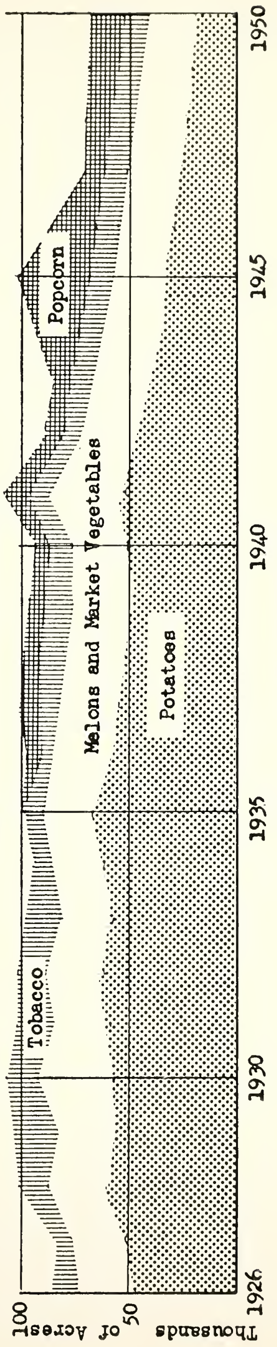


Fig. 4. Other special crops.

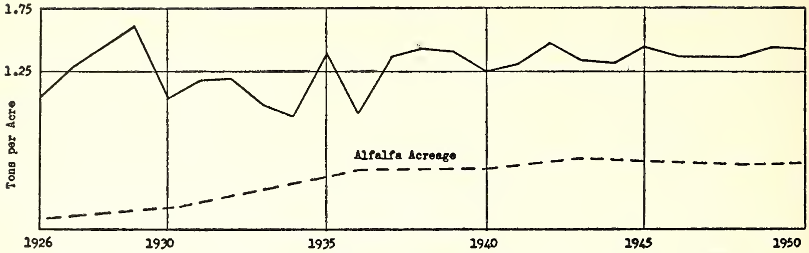


Fig. 5. Alfalfa acreage.

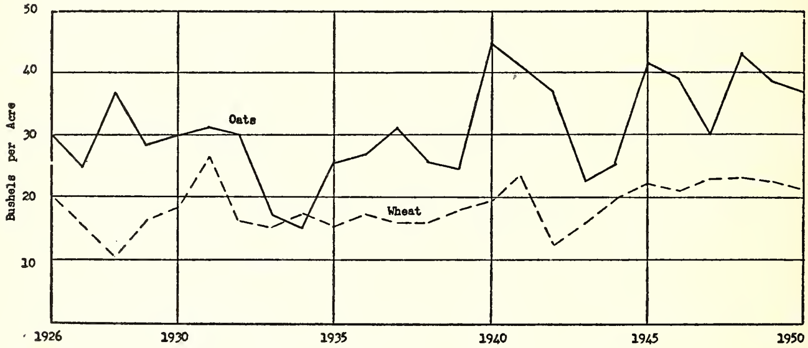


Fig. 6. Average yield per acre of oats and wheat.

Prior to 1935, popcorn was not considered worth reporting. In 1945, this crop was worth 2½ million dollars, twice the value of that year's rye harvest.

Having briefly considered some of Indiana's special crops, let us now go back to its prosaic crops.

It will be helpful if we remember the time element in the crop production cycle. For example, only four or five months may elapse between the time cornland is plowed and the grain is put in the crib. On the other hand, the wheat cycle is about twice as long, and encompasses more hazards.

Hay is affected by weather to an unusual extent. Once seeded, hay cannot be cultivated like field crops planted anew each year. Low winter temperatures, insufficient snow cover and drying winds kill hay. Alternative freezing and thawing at the break of winter uproots shallow-rooted hays like clover and timothy.

If the summer drought is moderate, the plants may be too short to reach the cutting blades on the mowing machine. A season of above-normal rainfall produces abundant forage, but frequently brings with it the problem of harvesting and curing. Optimum growing conditions are of little economic importance without several bright days at harvest-time.

A good year for hay seeds is one of moderate rainfall, well-spaced and slackening to dryness as the seeds mature. In 1940, the banner seed year of the quarter century, the hay seed crop was worth about 3⅓ million dollars.

The six years from 1930 to 1936 (Figure 5) were distinguished by the steady growth of alfalfa acreage. The superior qualities of alfalfa under conditions of sub-normal rainfall were effectively demonstrated during these years, especially in 1934 and 1936.

Clover and timothy, those traditional favorites, succumbed to drought in the springs of 1938 and 1939. Dramatic was the contrast between green alfalfa patches and brown clover and timothy fields. When summer weather met its requirements, alfalfa produced a high yield. As the alfalfa acreage curve has risen, the hay production curve has stabilized at a high level.

Starting in the mid-1940's there was a decline in the practice of cutting soybeans green for hay. Alfalfa had by that time proven its productivity, and it became profitable to let soybeans mature for grain.

We touched briefly on rye in our general discussion of trends. Although grown a little almost everywhere in Indiana, rye is concentrated in the three northern crop districts adjoining Michigan. The pronounced glacial topography of this section provides soils well-adapted to it.

Rye is sometimes used as an emergency crop. In 1931, for example, a cold dry spring discouraged some corn planting. Thus farmers turned to rye because it grows fast, and can be pastured, cut green for hay, or harvested as grain.

The average yield per acre of rye harvested in 1931 was low, for the expanded acreage had pushed rye onto unsuitable soils.

Early in this discussion, we noted the general definite decline in oats acreage. Heaviest north of Indianapolis, oats plantings increase in intensity toward the cool, moist Lake Michigan region.

Figure 6 shows a number of facts, the most obvious of which is the erratic yield of oats. Wheat has been rather consistent, and in the mid-1940's stabilized at a high level.

On a state-wide basis, the chart is also a comparison of how each fared. In 1928 and 1942 the relationship was inverse. However, the excellent wheat years of 1931, 1941 and 1948 were likewise good oats years.

Much of the land left idle by wheat killed in the 1927-28 winter was sowed to oats as an emergency crop in the spring of 1928. Not until 1940 was this year's yield surpassed.

The growing season of 1933 was hot and dry. The spring of 1934 was cold and dry; one-sixth of the oats acreage was abandoned. In 1935, oats headed poorly because wet weather encouraged plant growth rather than grain.

April, 1939, was wet and cold, followed by early growing-season drought. Abandonments reached 21% of seeded acreage, compared to about 5% normally. In addition, the Federal Government's A.A.A. branded oats a soil-depleting crop and threw its weight behind soybeans.

It is paradoxical that the best oats crop of the quarter century fell the next year. Seven years of the 1940-50 decade equalled or surpassed the 1928 high mark. Factors responsible included moist, temperate growing seasons, ideal harvest seasons and improved varieties.

The lowest point between 1935 and 1950 fell at 1943. The reason is

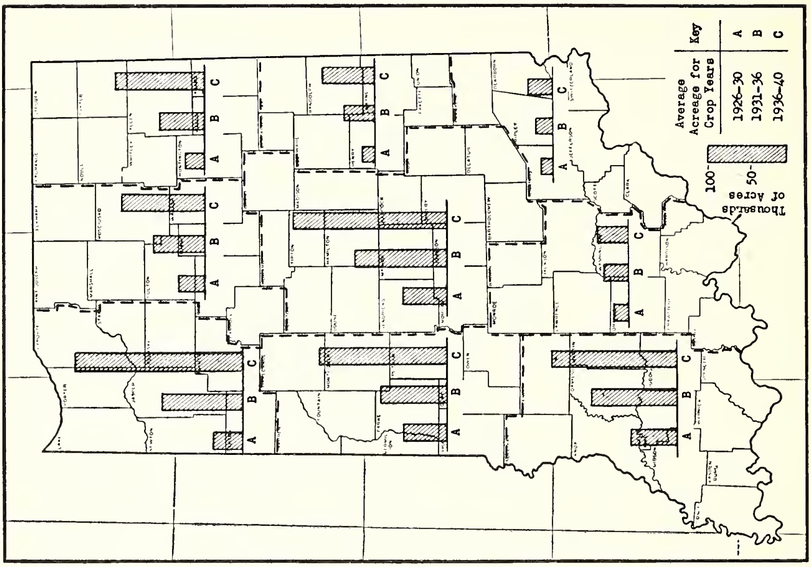


Fig. 7. Soybean acreage by crop districts.

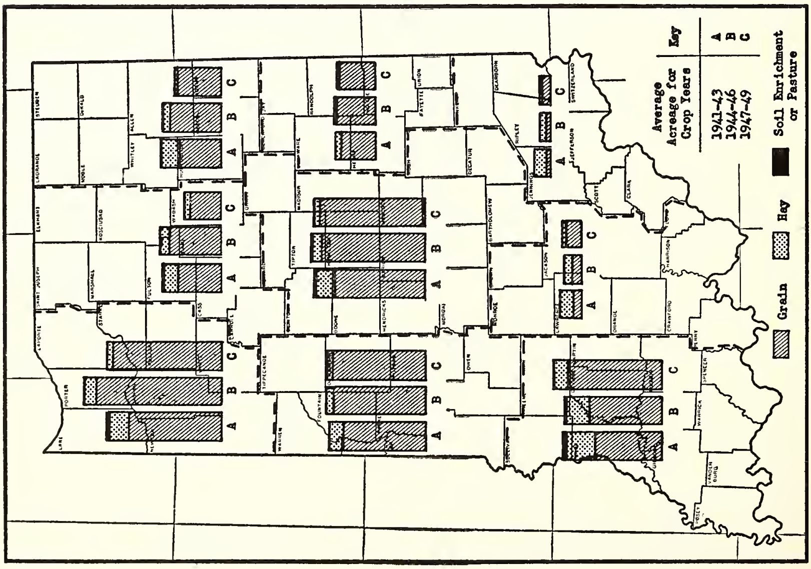


Fig. 8. Soybean use by crop districts.

geographical and most unusual. A great deal of corn was planted late that year. When the first brood of corn borers emerged, they had no corn to bore on. So in their emergency, they worked on oats.

While wheat is grown to some extent all over the state, the acreage is heaviest in the mid-central and southwestern sections. The dominant type is winter wheat. Like all crops planted so far in advance of harvest, winter wheat is subject to many vicissitudes of weather. The amount of snow cover affects the rate of survival in our state. Snow blankets the grain from killing, drying winds, and also assures a good supply of moisture once the growing season opens up.

Two of the most conspicuous valleys in wheat harvests are 1928 and 1942-43. So much wheat was killed by the winter of 1927-28 that 50% of the planted acreage was abandoned in the spring. The surviving wheat was thin, but made considerable recovery in May and June.

Both acreage and yield were down in 1942 and 1943. Drought and subnormal temperatures gave the crop a poor start in September and October of the preceding years. Many farmers withheld their normal plantings because they felt the seed wheat would not germinate.

Certain peaks stand out. The first of these is 1926, followed by 1931, 1941 and the uniformly high level prevailing from 1944 through 1950. The pattern is: A fall of favorable growing weather. Little winter kill. Precipitation below normal during winter and spring. May temperatures ideal for heavy stooling and heavy heading. Dry weather near maturity to hold down the spread of rust.

Wheat acreage in the period 1947-50 was higher than in the preceding decade, and above that of the war years. This increment took place across the northern two-thirds of the state, as improved varieties pushed the wheat frontier poleward.

All together, the most pronounced change in Indiana Harvests in the quarter century was the increase in soybeans. It is reported that United States production increased seven times from 1936 to 1948. In the same 12-year span, Indiana boosted its acreage about 30-fold (Figure 2), concurrent with 50% more average yield per acre (Figure 9).

Soybeans do well in the same situations as corn, and are ideally adapted to mechanized farming. By fitting nicely into a program of crop rotation, soybeans encourage sound land management policies. They are also more adaptable than corn to soil conservation measures like contour seeding.

The growth of soybean acreage by crop districts for the period 1926-40 is shown on Figure 7. It will be noted that the western one-third of the state and the mid-central district reflect the greatest increase.

Beginning with 1940 data as shown in Figure 8, more information is available on the three main farm uses for soybeans—grain, cut green for hay, and plowed under for soil enrichment. Two uses are dropping off: hay and soil enrichment. We have already seen that alfalfa has minimized the need for other hay. Further, soybeans fix nitrogen into the soil while they mature as grain.

It will be noted on Figure 9 that there is substantial agreement between soybean and corn production. Notches appear in both graphs at

1930, 1936 and 1940. Drought was responsible for 1930 and 1936. The spring of 1940 was cold and wet; the summer was hot and dry until well along. Soybeans this year suffered from drought at blooming time.

In 1938, wet weather delayed corn planting. Having a shorter growing season, soybeans came through all right. The 1949 yield per acre was high in the northern one-third and mid-central districts of the state. The full influence of hybrids was felt this year, giving soybeans an advantage in a mediocre corn season.

As we focus our attention on corn yield alone, at least three facts stand out. 1) The sawtooth profile, 2) the definite upward trend beginning with 1937, and 3) the few times in which there have been two good corn years in succession.

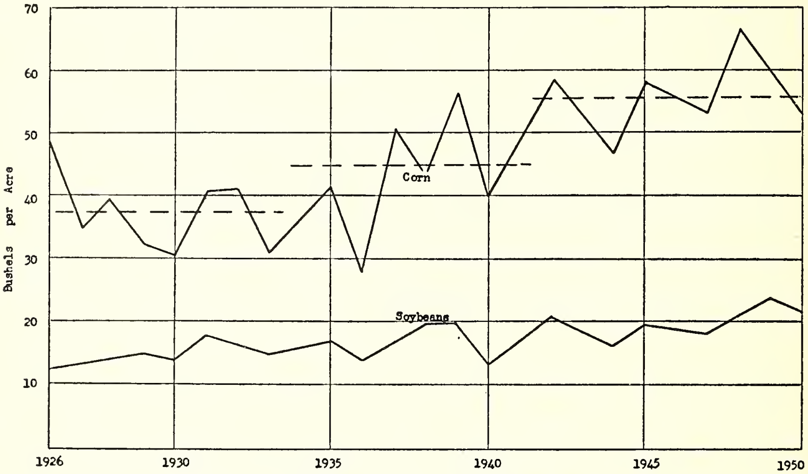


Fig. 9. Yields per acre of corn and soybeans.

The step average basis seemed most suitable for the purpose of summarizing annual corn yields. The steps (dotted lines, Figure 9) are averages of these inclusive periods: 1926-33, 1934-41 and 1942-50. The average yields per acre are 37.2, 44.7 and 55.5, respectively. The last figure is 1½ times as large as the first one.

Suppose we convert the difference in bushels per acre into acres of cropland. At the level of production prevailing from 1926 to 1933, our 1942-50 corn crop would have required about 2 million more acres of farmland. Improved farm technology and the use of hybrid varieties have made the difference.

The practice of planting hybrids gained momentum in the early 1930's, culminating in the 1937 upsurge. In effect, hybrids promote intensive agriculture yet are adapted to extensive methods.

Summary

During the quarter century 1926-50, Indiana agriculture was greatly helped by mechanization, generally helped but frequently hindered by cyclonic weather, and directly oriented by improved varieties.

Indiana agriculture benefited immeasurably because the terrain of the state is adapted to mechanized field operations. Perishable special crops also profited from the greater ease and speed with which metropolitan markets could be reached by motor transport. There was a substantial increase in the use of farm products as raw materials for industry.

Cyclonic weather dominates the complex of Indiana crop productivity. However, its relative weight declined in the quarter century as mechanization and hybrid varieties minimized its impact. Mechanization makes possible a great deal of essential farm work between changes in cyclonic weather. Fast-growing hybrids can redeem a late season or a short one.

Finally, the control of latitude over crops was reduced as the application of technology shifted crop frontiers.

Literature Cited

A detailed bibliography is not listed here but constant reference was made to some 200 separate crop summary reports and assessors' enumerations published by Purdue University in cooperation with the U. S. Department of Agriculture.

Our Highways, An Indian Heritage

Floy Hurlbut, Ball State Teachers' College

Before the coming of the white man, Indiana was an impenetrable wilderness. It was heavily forested, the forests choked with a dense cover of undergrowth and then entwined with wild grape vines. In the north and central parts, swamps were widespread, and the whole area inhabited by wild beasts and a few tribes of semi-nomadic Indians.

Because land transportation was so difficult, the earliest routes of the white man into Indiana were the waterways. Along the south, the Ohio gave access from Pennsylvania, Virginia, and the Carolinas. The Cumberland Gap was an easy passage from the Carolinas and Eastern Tennessee to Kentucky, down the Kentucky River to the Ohio and to one of the major crossings of the Ohio at Madison. The crossing above the Falls at Louisville was the route followed by George Rogers Clark into Indiana. There was a third crossing at Evansville and one at Lawrenceburg. Some of the early settlers continued on down the Ohio to the Wabash, and up the Wabash. The early history of Vincennes and New Harmony are well known.

In the northern part of the state, the St. Joseph was one of the early transportation routes up the river from its mouth at Benton Harbor, or La Salle's Fort Miamis, to the big bend at South Bend, then across a short portage to the headwaters of the Kankakee, down the Kankakee, the Illinois and Mississippi rivers to the Gulf. This was the route followed by La Salle in his journey to the mouth of the great "Father of Waters."

Another water route was by way of Lake Erie, the Maumee River, a short portage from the Maumee to the Little Wabash, and down the Wabash to the Ohio. All streams of any size were used by Indian canoes, and the White and Whitewater Rivers were later opened to heavier traffic by canals—the Whitewater canal, which gave access from the whole southeastern part of the state to the markets of Cincinnati, and the White-Erie canal, connecting Noblesville with the Maumee at Fort Wayne. (Fig. 1.)

Land travel in the early days was especially difficult, as has been stated. It is said that the Indians had a rather complex system of trails connecting their own settlements—they were friendly, and accustomed to easy visiting back and forth. That system of trails would be impossible to reproduce, but we have definite evidence of some of the major routes.

There seems to have been an easy ford across the White River near its junction with Fall Creek, toward which trails from all directions converged. Kentucky was a no-man's land at the time of the coming of the white man, left open as a hunting ground for the surrounding Indian tribes, and several of the major trails led from the north into Kentucky. After converging at the ford, the major trails followed down the Scottsburg lowland to Jeffersonville, roughly along the present Pennsylvania railroad and Highway 31. From the north converged the old trail of the

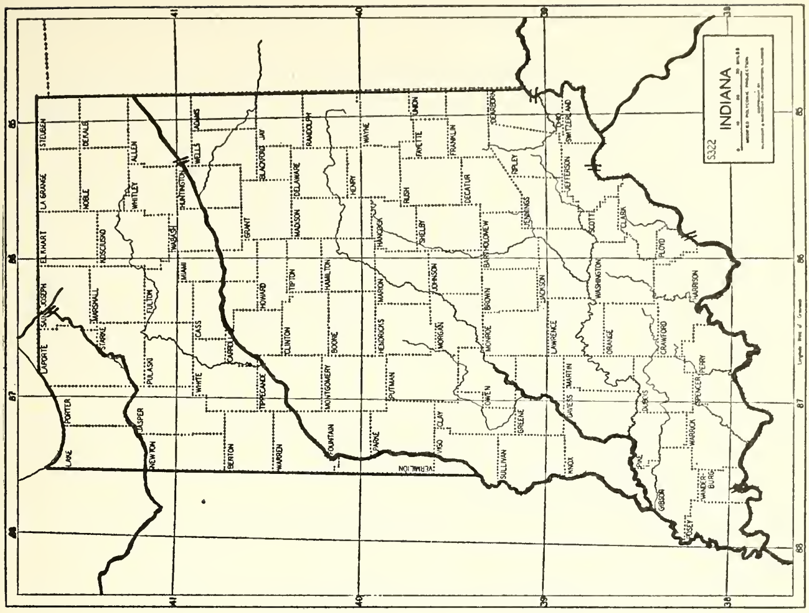
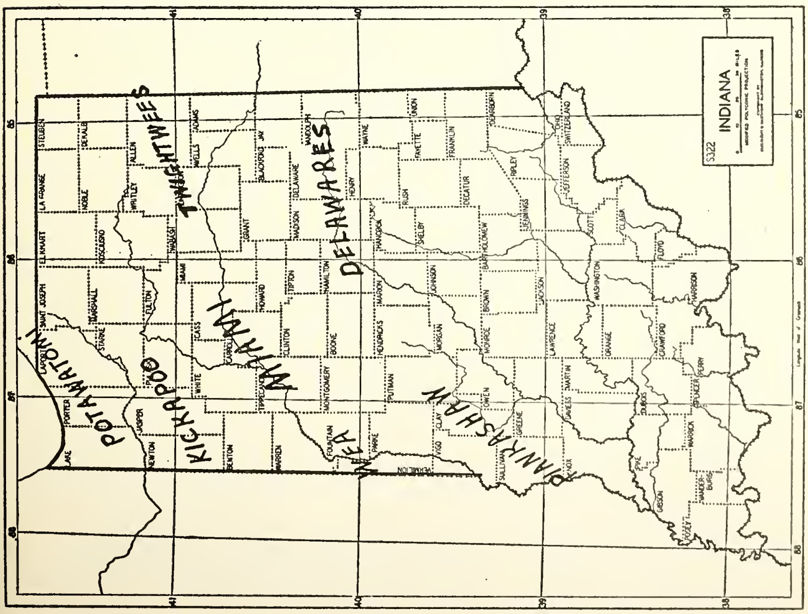


Fig. 1. Waterways Leading into Indiana in the Period of Exploration.



Fog. 2. Indian Tribes.

Pottawatomi, Kickapoo and Miami from near and north of the present Lafayette.

Another trail followed White River from the Delaware territory in the east central part of the state. It seems to have been the forerunner of our present Highway 32. The trail from Muncie and Winchester to Greenville lay along the south bank of White River, now only a locally travelled macadam road. Our present highway lies on the north side of the river and has been straightened. The Indian trail from Greenville down the Mississinewa to Peru on the Wabash is not exactly the present Frances Slocum Trail, but roughly parallels it. The Wayne trail, followed by Mad Anthony crossed the prairie in Grant County, from Fort Wayne, Huntington and Warren, to Summitville, Alexandria and the bend in the White River above Noblesville and on to the ford, roughly our present Highway 37.

The earliest highway to the north was the old Michigan trail, from Michigan City, South Bend, and Logansport to Indianapolis. It ran somewhat to the west of our present Highway 31. The old Conner trail, from John Conner's trading post on the Whitewater, to William Conner's trading post on the White, below Noblesville, was cut through what seemed to be a trackless wilderness to the white man, but along a route fairly distinct to the Indian. Highway 38 seems to be the modern highway nearest to the old trail. It forked at New Castle, one branch continuing to Muncie. There was a trail from Indianapolis to Vincennes, along the lower White River, our present Highway 67. Another came in from Ohio and the Whitewater Valley along the present Pennsylvania Railroad, our National Road. One came up to Indianapolis from Madison. Others could be traced.

"The earliest pioneers were benefited directly by the aboriginal trails; for not only did they follow them from one place to another through trackless wilderness in search of desirable regions, but their rude "traces" for subsequent ingress and egress were frequently only an improvement on the red man's narrow footpath." Straightened and shortened, they form our present highway system. (Figs. 2, 3, 4.)

The state road system of Indiana was not begun until four years after the state was admitted to the Union. Meanwhile, other trails provided routes for or were developed by the white man. One, a buffalo trace, crossed Dubois County and south Orange County, but it is almost obliterated today. The herds of buffalo in Indiana and southern Illinois crossed Dubois and Pike counties, Orange County down to the Ohio Falls and to the salt licks of Kentucky. Interestingly, the first white settlements in Dubois and Pike counties occurred along this trail in the northern part of the counties. Many other such traces existed.

There seems to be an interesting correlation between the sites of Indian villages and our towns and cities. Some writers tell us that Indian villages and towns were not permanent, but some, perhaps many of them, appear to have become so. Fort Wayne is one of the best illustrations. The Indian village was a Miami village and was called Kekionga. The settlement located on the present site of Lafayette consisted of five villages, almost continuous. Fort Quiatanon is best known. Les Gros was on or near the site of the present Lafayette.

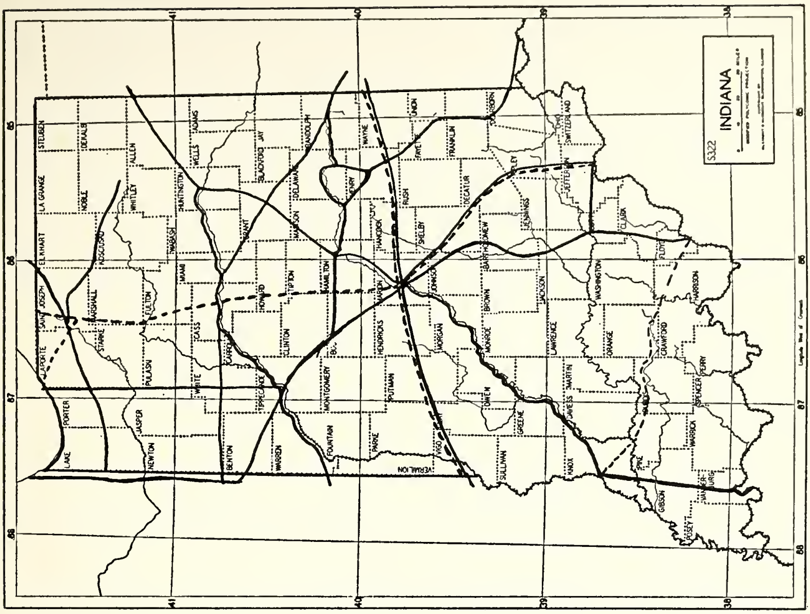


Fig. 3. Pattern of Indian Trails and Early Highways.

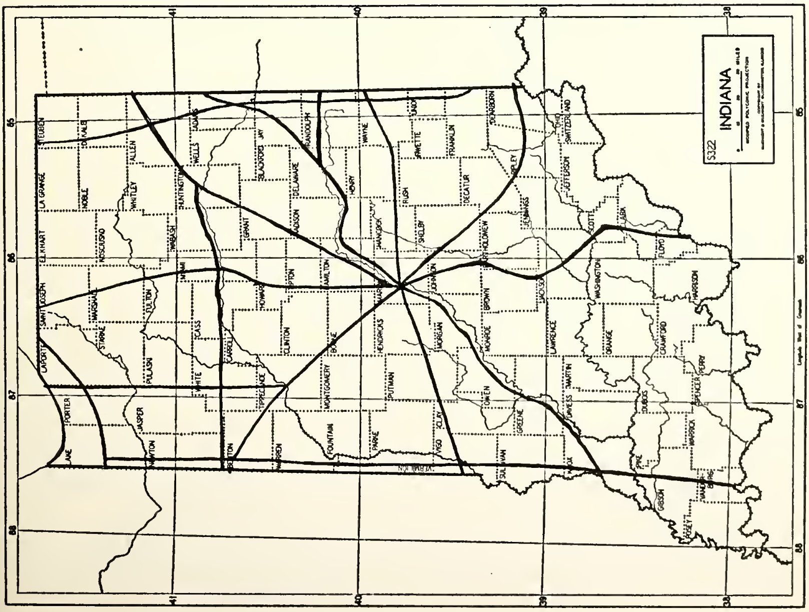


Fig. 4. Pattern of Present Highways.

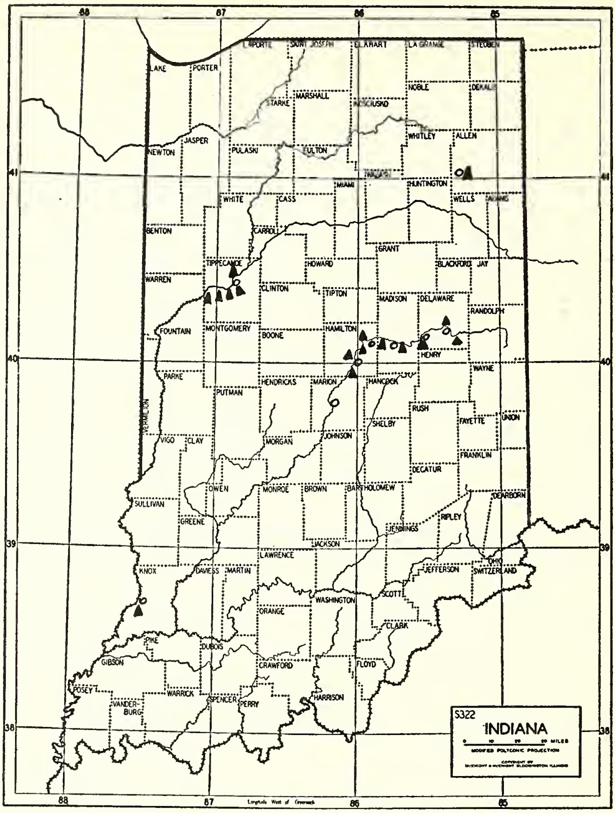


Fig. 5. Relation of Delaware Villages along White River to our Cities and Towns.

The labor involved in developing these early trails into highways was tremendous. It was difficult in the southern part of the state, and the poll tax took the form of two days of labor annually on the roads. In the north where swamps made the laying of corduroy and plank roads a necessity, it was more difficult. Four days of labor annually were demanded. Eventually toll roads became popular.

The Delaware villages on the White River make a good example of the relationship of the two types of settlements. The easternmost was near the bend of the White, about three miles below Muncie; Muncytown on high land north of the big bend in the river where the statue "Ode to the Great Spirit" is located. There was another village near our present Yorktown; Andersontown on the present site of Anderson; Nancytown, Indian Strawtown, Saratown, Upper Delaware Town and Lower Delaware Town. Noblesville was located between the last two. (Fig. 5.)

There was no settlement on the present site of Indianapolis. The Indians chose high land, overlooking streams or rivers. Indianapolis is on low land, in an unhealthful area. It was located near the boat landings on the river, but most of the settlers became ill within the first year, and many died. The settlement persisted in spite of unhealthful conditions and has become our most populous city, our state capital, the hub of our transportation systems, a cultural, manufacturing, and trading center.

In conclusion, the rectangular road pattern in Indiana is overlain by another pattern which has no relation to the first. The second pattern is very similar to the pattern of old Indian trails. One wonders if the geographic factors which influenced the Indians in the location of their trails are still operating today; whether the influences operating today are largely man-made; or whether our main highway system is a simple heritage from the Red man who formed his trails by travelling single file along the easiest routes through a trackless wilderness.

Curves of Population Change in Indiana 1850-1950

R. L. GENTILCORE, Indiana University

The record of population change for the State of Indiana in the period 1850-1950 has been one of constant growth. Actually the population curve closely approximates a straight line (Fig. 1), reflecting the gradual transition in the state from a predominantly agricultural to a more and more industrial economy. However, different sections of the state have contributed unequally to this growth and shared unequally in its fruits. One of the most significant aspects of the geography of a region is the study of such changes, their classification and as far as is possible, their explanation. The object of this article is to classify the changes in a preliminary way. Explanations and the drawing of relationships have not been attempted except incidentally. These will come later when sufficient material has been gathered.

Population change is best shown by the population curve which graphically portrays two very important items—total numbers and the change in numbers from one census year to another. For this study, population curves were drawn for each of the 92 counties in the state for the period 1850-1950, the curves compared and finally the counties grouped on the basis of similarities in the curves. The grouping then has been in terms of (i) total population numbers and (ii) the change in these numbers between census years. The groupings follow:

I. Counties with more than 100,000 population in 1950. There are five counties in this group, three in the northern part of the state (Lake, St. Joseph and Allen), one in the central part (Marion) and one in the southern part (Vanderburgh) (Fig. 2). Growth has been continuous and steady and directly related to increasing industrialization. These counties contain the largest cities—Indianapolis, Gary, Fort Wayne, Evansville and South Bend. The curve for Marion County (Fig. 1) is shown as an example of the group. In 1950 these counties had more than one-third (37.4%) of the state population.

II. Counties with 50,000-100,000 population. There are eight counties in this group. In two of them, both in the northern part of the state (LaPorte and Elkhart) growth has been steady. In the remaining six, all in the central part of the state (Fig. 2), there was a decline in growth for a short period around 1900. The curve for Wayne County (not illustrated) is typical. The group had seventeen per cent of the state population in 1950. As in Group I, these are counties with large urban populations.

III. Counties under 50,000 population.

A. Counties with a population peak before 1910. This group contains 43 counties with a little less than one-fifth of the state population in 1950 (19.2%). Rural population predominates in all the counties, in marked contrast to the situation in the first two groups.

There are three divisions within this group. In the first, the population curve indicates a continuous decrease since the year of the popula-

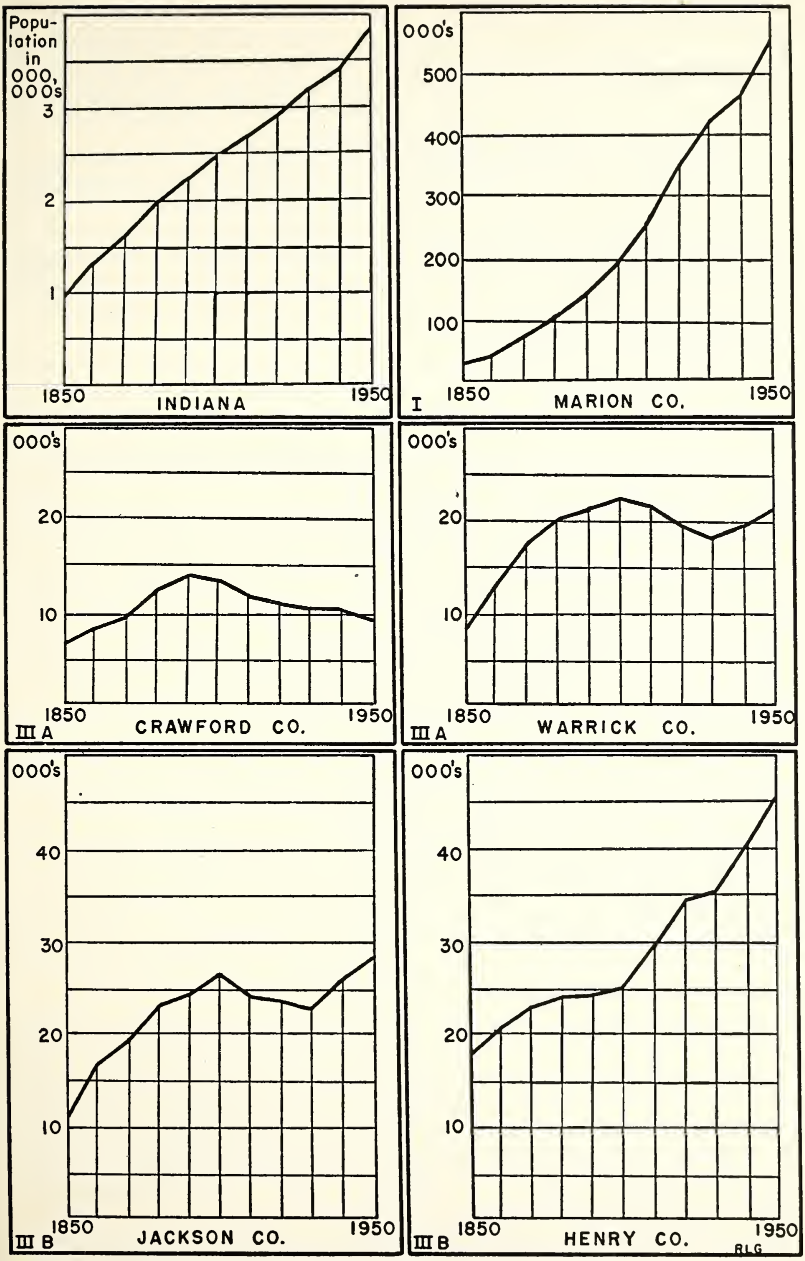


FIG. 1. POPULATION CURVES FOR INDIANA AND FOR COUNTIES REPRESENTATIVE OF POPULATION GROUPS I, III A, III B.

tion peak. There are fourteen counties in this division. Seven are in the southernmost part of the state (Fig. 2) where decline has accompanied the loss of timber and soil resources. The other seven are in the coal producing sections in the west central part of the state where decline has followed the abandonment of mines. The curve for Crawford County is typical with its peak in 1890 and decline since then (Fig. 1).

Counties in the second division show a significant rise in population in the period 1930-1950. There are eighteen counties scattered throughout the state with no concentrations in any particular area (Fig. 2). It would appear that a number of factors varying probably from one area to another has been responsible for the surge in the last twenty years. Typical of the group is Warrick County with its peak in 1900, a decline to 1930 and an increase to 1950 (Fig. 1).

Counties in the third division have population curves intermediate between those of the two divisions just mentioned. The pre-1910 peak is obvious and the decline is continuous to 1930 but between 1930 and 1950 there is a very slight rise. The increase amounts to less than five per cent of the figure for the peak population year and thus sets these counties apart from those in the previous division where the increase has been much more significant. In some cases, the rise has taken place only since 1940. There are eleven counties, again scattered throughout the state with no more than two contiguous in any area (Fig. 2). Many of these counties contain productive farmland but increased mechanization may have been responsible for population decreases. The curve for Tipton County is typical (Fig. 1). The population peak is in 1900; there is a decline to 1940 and a slight increase to 1950.

B. Counties with a population peak in 1950. This group embraces 31 counties and accounted for more than one-fifth (22.7%) of the state population in 1950. There are two divisions. In the first which has 24 counties a secondary peak of population was reached before 1920. The curve for Jackson County is typical (Fig. 1). There is a definite peak in 1900, followed by a decline to 1930 and an increase from 1930 to the highest population in the county's history in 1950. Two concentrations of counties in this division appear from the map (Fig. 2)—one in the central part of the state, extending south to the Ohio River, and the other in the north, extending as an east-west band south of the northernmost tier of counties.

The second division within this group has no secondary population peak. Increase has been constant to 1950, although rates have varied. The curve for Henry County is typical (Fig. 1). Most of these counties contain at least one fairly large city (Kokomo in Howard County, New Albany in Floyd County and New Castle in Henry County) which has dominated or controlled the curve of growth. With few exceptions, this is not the case with counties in the first division. Here rural population has been predominant throughout.

C. Counties with a population peak 1920-1940. This group is made up of the "left-overs," those counties which do not fit into any of the other designations. A slight change in definition, however, may result in their inclusion in one of the above groups. The counties include Lawrence with

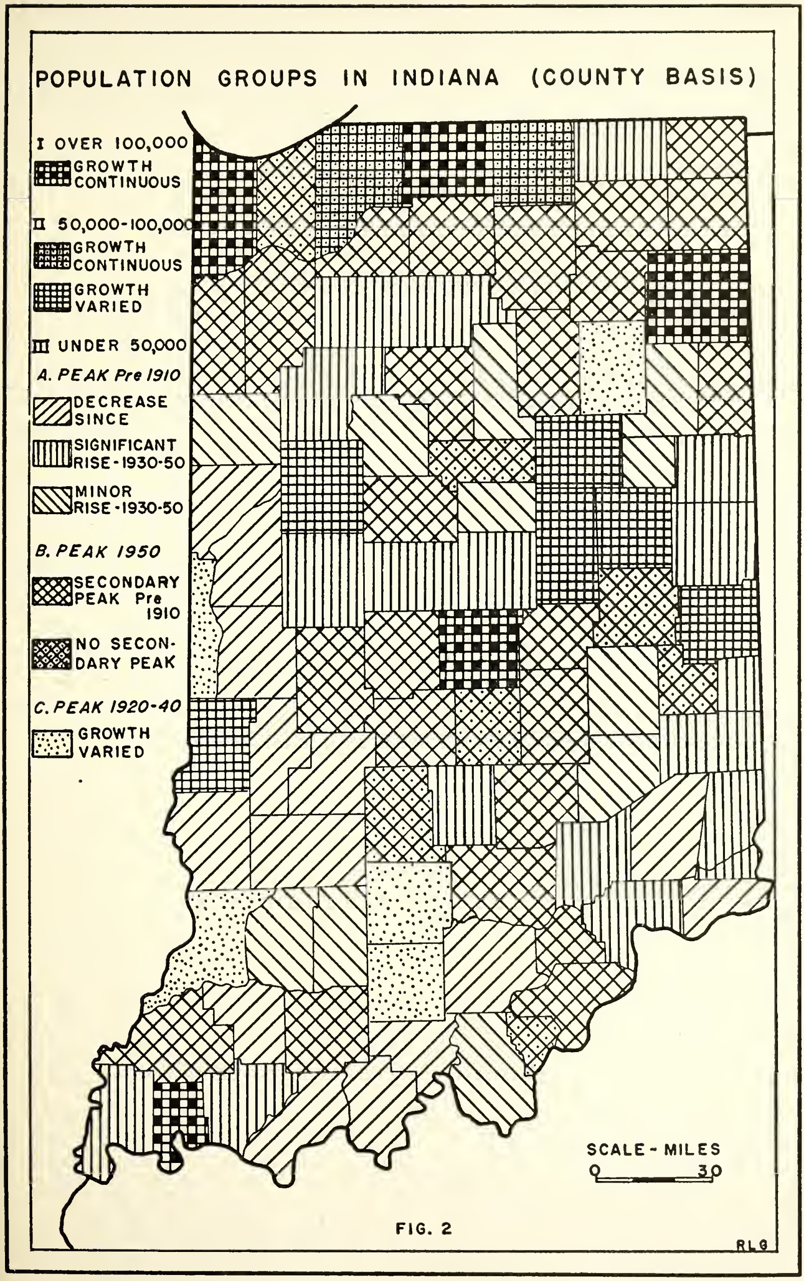

POPULATION GROUPS IN INDIANA (COUNTY BASIS)
I OVER 100,000
GROWTH CONTINUOUS
II 50,000-100,000
GROWTH CONTINUOUS
GROWTH VARIED
III UNDER 50,000
A. PEAK Pre 1910
DECREASE SINCE
SIGNIFICANT RISE-1930-50
MINOR RISE-1930-50
B. PEAK 1950
SECONDARY PEAK Pre 1910
NO SECONDARY PEAK
C. PEAK 1920-40
GROWTH VARIED
SCALE-MILES
0
30
RLG

FIG. 2

a peak in 1930 and a gradual decrease since; Vermillion and Knox in the coal mining section of the state with peaks in 1920 and a general decrease (especially striking in Vermillion) since; Orange, which is rural only, with a peak in 1930 and a decrease since and finally Huntington which is similar to the rest in its population peak (1920) but differs from them in that its population has been increasing since 1930.

Appendix

COUNTIES IN POPULATION GROUPS

I. Over 100,000. Allen, Lake, Marion, St. Joseph, Vanderburgh.

II. 50,000-100,000
  Growth Continuous. Elkhart, LaPorte.
  Growth Varied. Delaware, Grant, Madison, Tippecanoe, Vigo, Wayne.

III. Under 50,000
  A. Peak pre-1910
    Decrease Since. Clay, Crawford, Fountain, Greene, Owen, Parke, Pike, Perry, Ripley, Spencer, Sullivan, Switzerland, Warren, Washington.
    Significant Rise 1930-50. Boone, Brown, Dearborn, Franklin, Fulton, Hamilton, Jay, Jefferson, Jennings, Lagrange, Montgomery, Ohio, Posey, Pulaski, Randolph, Union, Warrick, White.
    Minor Rise 1930-50. Benton, Blackford, Carroll, Daviess, Decatur, Harrison, Martin, Miami, Rush, Tipton, Wells.
  B. Peak 1950
    Secondary Peak Pre-1910. Adams, Bartholomew, Cass, Clark, Clinton, DeKalb, Gibson, Dubois, Hancock, Hendricks, Jackson, Jasper, Kosciusko, Marshall, Morgan, Newton, Noble, Putnam, Scott, Shelby, Starke, Steuben, Wabash, Whitley.
    No Secondary Peak. Fayette, Floyd, Henry, Howard, Johnson, Monroe, Porter.
  C. Peak 1920-1940. Huntington, Knox, Lawrence, Orange, Vermillion.

HISTORY OF SCIENCE

Chairman: R. E. GIRTON, Purdue University

C. L. Porter, Purdue University, was elected chairman for 1953

ABSTRACTS

Scientific contributions made by Indiana's colleges and universities, 1870-1950. STEPHEN S. VISHER, Indiana University.—During 1870-1950, most of the scientific research done in Indiana was done by members of the faculties of its higher educational institutions. Nearly all of these institutions contributed significantly at some period. Most of them also produced alumni who became notable scientists.

In **Indiana Scientists** are brief biographical sketches of about 4,000 scientists born in Indiana, graduated there, or employed at least briefly there. The sketch indicates something as to the special interests of the scientist, where he worked, and the recognitions received.

For nearly all of the Indiana colleges and universities, a historical summary is given of the institution's contributions to science, listing the former and some present faculty members who contributed conspicuously, and the more distinguished alumni. For several, the dates of the inaguration of certain scientific curricula are given.

During the first two or three of the eight decades under discussion, Hanover, Wabash, Indiana, DePauw and Rose Polytechnic ranked especially high. In recent decades, Purdue, Notre Dame and Butler have become prominent, while some of those who ranked high in the early decades have declined relatively. Other phases of the history of science in Indiana given in this volume are summaries for each of several sciences of their development in Indiana, and listings by institutions of the presidents of the Indiana Academy of Science, and other especially distinguished scientists.

Some theories of origins. JAMES F. MACKELL, Indiana State Teachers' College.—There is probably no scientific field better adapted to a study of the history of science than the field of Cosmogony. Ever since man has been able to record his history there have been attempts to speculate on the origin of the Universe and upon his own place in that Universe. Many years ago the German philosopher Kant and the French mathematician Laplace proposed the well known Nebular Hypothesis. Later two American scientists, Chamberlin and Moulton, University of Chicago, proposed a radically different idea known as the Planetessimal Hypothesis. In recent years there seems to be a tendency to revert to an hypothesis somewhat similar to that of Kant and Laplace but based upon recent developments in the field of nuclear physics. Thus it appears that a study of the history of the development of these ideas is pertinent in an attempt to solve the riddle of nature and the Universe.

A century of the American Pharmaceutical Association, 1852-1952. CHARLES O. LEE, Purdue University.—A brief account of the circumstances which led to the organization of the American Pharmaceutical Association, how it has functioned through the years, some of its accomplishments, its place as a national association, and its centenary program in Philadelphia, August 17-23, 1952.

Review of attempts to define THE scientific method. WARREN E. HOWLAND, Purdue University.—It is one thing to use a scientific method; it is quite another to attempt to put the essence of the procedure into words so as to characterize THE scientific method,—if there is ONE. Perhaps there never was a time since men have been men when methods properly called scientific have not been used for the solution of problems. But only recently—so it seems to this writer—have satisfactory verbal descriptions or definitions appeared. Some of the contributions to this enterprise of Pascal, Des Cartes, John Locke, J. A. Thompson, Jevons (of Jevons' Logic), Graham Wallas, John Dewey and several others will be referred to in this brief paper in the attempt to formulate a statement which embodies a pattern or list of steps in the thinking process which are characteristic of nearly all, if not all, of the planned and successful methods for solving problems.

Rafinesque and the taxonomy of Indiana vascular plants. RAY C. FRIESNER.—The paper presents a summary of Rafinesque's work dealing with the taxonomy of Indiana plants. Of the 1,210 names proposed by him Gray's Manual, 8th ed., lists only 33 as valid names. Of the 654 species and varieties to which Rafinesque gave names, 285 were given two or more names each by him. One specific case to be cited is *Prunella vulgaris.* He had given this plant 18 different names. Only 2,73 per cent of the names he proposed are now in use. [This abstract has been prepared by John E. Potzger and the entire paper will appear in the Butler Botanical Studies.]

A short history of fungus antibiosis and its industrial, medical and economic significance. CHARLES L. PORTER, Purdue University.—A review is given of the observations made by laboratory and field workers concerning the common incidence of mixed cultures and the phenomena associated with such cultures. The various types of microbiotic associations are discussed, as well as the practical applications either suggested or in current use that are made of such associations.

The Domestication of Bumblebees. B. ELWOOD MONTGOMERY, Purdue University.—Both Carl Vogt and Ernst Haeckel expressed the opinion that the English nation owed its power and wealth largely to bumblebees. This opinion was based on the following logic. One of the important foundations of the wealth of England is found in cattle which feed principally on red clover. In the absence of bumblebees this plant produces little or no seed in most localities.

Darwin appears to have been the first to point out the importance of bumblebees in the pollination of red clover in 1859. The matter of red clover requiring bumblebees for pollination was the center of a bitter dispute for many years. However, the importance of bumblebees was established beyond a doubt in the years following 1885. In that year bumblebees were introduced into New Zealand where no red clover had been produced previously, even when honeybees were placed in the fields. Within five years yields of 500 to 600 pounds of seed per acre were obtained regularly.

Little work has been done on the domestication, or even the management of bumblebees, although they are close relatives of the honeybee, an animal which has been living in close association with man, if not under actual domestication, longer than any other animal except the dog.

The first attempt to establish bumblebee colonies in artificial domiciles was made by Hoffer at Graz in 1882. Nest establishment was started but complete colonies were not obtained. Advances were made with European species by Lindhard (1912) and Sladen (1912). Establishment of nests by American species in cages or artificial domiciles was obtained by Frison in Illinois (1918, 1927) and Plath at Boston (1934).

Hasselrot (1952) in Sweden has recently described a method of starting nests in cages, after which the domiciles are placed in the field and opened so that the queens continue the development of the colonies in the natural manner but under management.

During the past two years the author has developed domiciles and methods by which colonies have been carried through all stages of the life cycle in confinement. Colonies have been used, either in cages, or in open domiciles, for experimental work on alfalfa, red clover, mint and tomatoes.

Thirty-four years of science at Ball State Teachers College. O. B. CHRISTY and R. H. COOPER, Ball State Teachers College.—This paper is an account of the work of some of the staff members and former students of the Science Department of Ball State Teachers College at Muncie, Indiana. Included especially are those on the staff and those in other positions at this time who have contributed noticeably to the teaching profession and to science research. In the brief accounts are notations of the work of some alumni who have added to the knowledge and accomplishments in the field of science.

Recent developments in science in Soviet Russia. ALLAN B. BURDICK, Purdue University.—The background and personnel involved in the demise of genetics teaching and research in Soviet Russia is reviewed. An attempt is made to evaluate the basis for the ensuing controversy by drawing on recent pertinent experimental findings. The impact of the genetics controversy on other branches of Soviet science is traced through a series of recent reports. The evidence indicates that the present situation in Soviet science is the result of a different philosophical basis of science.

A dominant force in our world and its significance for democracy. ZYLPHA HURLBURT, Anderson College.—It is evident to every thinking observer that there are two opposing ideologies in our world, viz., democracy and totalitarianism. Regardless, science plays a dynamic role in shaping human lives and influencing state and world progress. Without science, living would be reduced to a status of crudity. Could we survive?

We profit by accumulative findings of science. Philosophies have been altered by science; major concepts of power revised; future changes are inevitable.

A changing economic order may mean advance or retrogression. Science itself is neither good nor evil. Can it help us, now? Survival depends upon a continuance of scientific endeavor. Science is universal. What of planning and controls in scientific research?

Science, like all truth-seeking activities of man, requires a free environment, free from fear, petty arbitrariness and tyranny.

Pioneer Microscopists of the Seventeenth Century

RAYMOND E. GIRTON

Introduction

As compared with the preceding and succeeding centuries, the seventeenth century was one of outstanding achievement in the field of microscopy. The microscopes which were made and used during this century had been perfected to as great a degree as was possible until the use of achromatic lenses was achieved. This latter accomplishment did not take place until the nineteenth century. As the result, the advancement made in the seventeenth century was not continued during the eighteenth, and progress in microscopy lay dormant for over a hundred years. The lives of Hooke, Leeuwenhoek, Malpighi, Grew, and Swammerdam therefore mark a period of brilliant success in the early history of this subject. In this paper it is desired to discuss at some length the lives and work of the first three of these men.

Robert Hooke (1635-1703)

Robert Hooke was a versatile experimenter in many different fields. He was born at Freshwater, Isle of Wight, where his father was minister of the parish. After some early tutoring followed by a period of schooling at Westminster, Hooke entered Christ Church College, Oxford, at the age of 18. He made good use of his opportunities there, and two years later was employed by Robert Boyle in scientific work including the construction of a famous air pump. Through the influence of Boyle, Hooke was appointed curator of the Royal Society at the age of 27, and elected to fellowship in the Society the following year. A year later he received an appointment of a "mechanical lectureship" carrying £50 per year. This lectureship was instituted by Sir John Cutler for the especial benefit of Hooke. The year following he was nominated Professor of Geometry in Gresham College. Hooke took up permanent residence there for the rest of his life.

After the "Great Fire" of 1666, Hooke constructed and submitted a model for rebuilding the city of London. This model was highly approved although the one submitted by Sir Christopher Wren was given preference. Hooke, however, acted as surveyor and accumulated several thousand pounds as the result of this lucrative appointment. After his death, this money was discovered in an old iron chest which had evidently remained unopened for over 30 years.

For a period of five years (1677-1682), Hooke served as secretary of the Royal Society. During this time he published the papers read before the society under the title of "Philosophical Collections." This appeared in the years 1681-82.

In 1691 Hooke was granted an M. D. at Doctors Commons when 56 years of age. Five years later he received a monetary grant from the Royal Society for the purpose of enabling him to finish his philosophical inventions. Death at the age of 68, however, prevented the completion of this task.

As to his appearance, may I quote briefly from an English author.[1] "In personal appearance, Hooke made but a sorry show. His figure was crooked, his limbs shrunken, his hair hung in disheveled locks over his haggard countenance."

Many circumstances served to embitter Hooke and render him unpopular in the latter years of his life. These circumstances included a protracted controversy concerning the advantages of telescopic over plain sights, the death of a well loved niece, a law suit over his salary, and repeated anticipation of his discoveries which inspired him with a morbid jealousy.

In spite of Hooke's fine mental endowment and good scientific training, he cannot be considered a scientist of the "first water" because his interests were too diversified. According to one author, Hooke "originated much, but perfected little." At the same time, the list of his achievements is impressive. Here are some of his contributions.

Hooke:

(1) adopted a form of undulatory theory of light,

(2) anticipated the doctrine of interference,

(3) independently observed diffraction,

(4) was the first to state clearly that the motion of the heavenly bodies is a mechanical problem,

(5) approached the discovery of gravitation,

(6) invented the wheel barometer,

(7) discussed the application of the barometer to weather forecasting,

(8) suggested a system of optical telegraphy,

(9) investigated the nature of sound,

(10) investigated the function of air in respiration and combustion,

(11) originated the use of the pendulum for measuring gravity,

(12) invented anchor escapement for clocks and spiral springs for watches, and

(13) constructed and made extensive use of a compound microscope.

It is the latter achievement which I wish to consider briefly at this point. Hooke's microscope was a compound microscope consisting of two lenses—an objective lens and an eye piece lens. Horizontal and vertical adjustments were effected by sliding mechanisms with thumb screws for locking in position. The microscope was focused by means of spiral screw threads on the lower end of the barrel. Objects under examination were impaled upon a sharp pointed spindle which in turn was mounted on the microscope base. Light for illuminating the experimental objects was focused by means of a planoconvex lens.

Hooke carried out a great number of observations upon a very diverse list of subjects. These he published in his "Micrographia" in 1664. This book was the first of its kind. In it, Hooke, with the aid of over eighty plates of figures, described his microscope and numerous observations on the minute structure of various objects including charcoal, sponges, book worms, and cork. This work of Hooke's gave great impetus to microscopical study, especially in England. In this book he pictured and described, probably for the first time, the cellular structure of plant tissues. A selection from the chapter entitled "Of the Texture of Cork" is therefore of considerable interest to botanists. "I took a good clear piece of cork . . . (and) cut off . . . an exceeding thin piece of it . . . and casting the light on it with a deep plano-convex glass, I could exceeding plainly perceive it to be all perforated and porous, much like a Honey-comb in these particulars. First . . . it had very little solid substance in comparison of the empty cavity that was contained between . . . Next . . . these pores, or cells, were not very deep, but consisted of a great many little Boxes, separated out of one continued long pore, by certain Diaphragms."

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[1] Richard Waller, then Secretary of the Royal Society of London.

"Nor is this kind of Texture peculiar to cork only, for upon examination with my Microscope, I have found that the pith of an Elder, or almost any other Tree, the inner pulp or pith of the cany hollow stalks of several other vegetables . . . have much such a kind of Schematisme, as I have lately shown that of Cork."

Anthony van Leeuwenhoek (1632-1723)

Leeuwenhoek, famous Dutch microscopist, was born in Delft, Holland, in 1632. When still but a boy, he was sent to Amsterdam where he worked at the cloth trade for a time. After several years, he returned to Delft where he married at the age of 22. Six years later he accepted a minor political office, "Chamberlain of the Sheriff," which he held for 39 years, and then retired on full pay. The duties, as well as the salary were, however, light. The salary amounted to £26 per year, but since certain members of the family had acquired wealth in the brewing industry, Leeuwenhoek evidently possessed sufficient funds to keep soul and body together for better than 90 years.

Leeuwenhoek early became interested in magnifying lenses, probably while working in the draper's shop in Amsterdam. Certainly, while there he learned to use the magnifying glass which drapers then used to count the threads in their goods. This interest led him to master the art of grinding fine lenses, and to the manufacture of microscopes of his own design. He found single lenses of very short focus to be preferable to the then existing compound microscopes. Leeuwenhoek's lenses were small and of great curvature. They gave a small field, but clearer definition than such compound microscopes as that of Hooke. Most of Leeuwenhoek's lenses were made of glass, but a few were made of rock crystal, and according to one author Leeuwenhoek even tried diamond as a lens material. Each lens was mounted between two metal plates. The object was held on a pin, unless of liquid nature, in which case it was placed on a thin glass or mica plate. Adjusting screws were used to bring the object into the desired position before the lens. The largest of these screws served as a handle for the instrument.

It is interesting to note that some of Leeuwenhoek's microscopes were constructed for examining and comparing two or even three objects. He made different microscopes to suit different purposes, so that he is said to have owned some 247 microscopes, besides 172 lenses set between metal plates. This brings the total to 419 lenses which he made. The magnifying powers of these lenses varied from 40 to 270 diameters. The metal plates, which formed an important part of the microscopes, were of copper in some instruments, silver-bronze in others, and even of silver or gold in still others.

In 1673, Leeuwenhoek, at the age of 41, was introduced to the English Royal Society by his fellow countryman, De Graaf. Thus began a stream of scientific communications from Leeuwenhoek to London which resulted in the publication of 112 distinct papers in the "Philosophical Transactions." Seven years after his introduction, Leeuwenhoek was elected a fellow of the Royal Society and presented with a medal in token of esteem. In gratitude to this body, Leeuwenhoek willed the Royal Society 26 of his microscopes. He notified them of this fact 22 years before his death in a letter, a portion which reads as follows: "I have a small black cabinet, lackered and gilded, which has 5 little drawers in it, wherein are contained 13 long and square tin boxes covered with black leather. In each of these boxes are 2 ground microscopes, in all 6 and 20: which I did grind myself and set in silver; and most of the silver was what I extracted from minerals; . . . and an account of each glass goes along with them."

"This cabinet . . . I have directed my only daughter to send to your Honors, as soon as I am dead, as a mark of my gratitude, and acknowledgement of the great honor which I received from the Royal Society."

In 1697 Leeuwenhoek was elected a corresponding member of the Paris Academy, and as a result, published 26 papers in the "Memoirs" of this society.

Leeuwenhoek remained active in his work up to within 36 hours of his death. He died in his native city, Delft, and was buried in "The Old Church" of that city. A translation of a portion of his epitaph runs thus:

"Here lies Antony van Leeuwenhoek, oldest member of the Royal Society of England, born at the city of Delft the 24th of October, 1632, and died the 26th of August, 1723, having reached the age of 90 years, 10 months and 2 days."

"You, O wanderer, having respect for old age and wonderful talent, stand in veneration. Here gray science lies buried with van Leeuwenhoek."

Something should now be said concerning Leeuwenhoek's personal attributes and scientific contributions. As may be gathered from the foregoing discussion, he did not have the advantage of a thorough schooling, but was largely self-trained. His schooling ended at the age of 16. He was ignorant of all languages save his own. This handicapped him greatly in the exchange of ideas with individuals of other countries who were interested in scientific pursuits. Thus thrown on his own resources, he spent his time and energies in the careful and painstaking collection of more or less unrelated facts. But his facts were accurately observed and carefully recorded. One contemporary author states that Leeuwenhoek had not only constructed the finest microscopes, but that he also had the keenest eye in Europe.

Leeuwenhoek's studies with the microscope resulted in a long and impressive list of discoveries. Important among them are these:

(1) confirmation and extension of Malpighi's demonstration of blood capillaries,

(2) first accurate description of red blood corpuscles (circular in man, oval in frogs and fishes),

(3) discovery of spermatozoa in dogs and in other animals including man,

(4) investigation of the structures of the teeth, lens of the eye, and muscle fiber,

(5) observation that yeast consists of minute globular particles,

(6) observation of the characteristically different structures of monocotyledenous and dicotyledenous stems,

(7) accumulation of evidence opposing the idea of spontaneous generation—weevils from eggs, not from wheat; fleas from eggs and larvae, not from sand, dust, pigeon dung, or urine; mussels from spawn, not generated from mud or sand; eels from previous forms, and not from dew as held by many "respectable and learned men,"

(8) discovery of protozoa, and

(9) the discovery of bacteria.

Marcello Malpighi (1628-1694)

Another versatile investigator of this period was Marcello Malpighi, an Italian physician. Malpighi was born near Bologna of peasant parentage in 1628. His parents, however, were financially able to give him the advantages of a good education. This they did, and at an early age he entered the University of Bologna where he devoted himself to the study of Aristotelean philosophy. After a break of two years in his studies owing to the death of his parents, he returned to the University and took up the study of medicine. This he completed in 1653 at the age of 25.

Several years after, Malpighi was appointed professor of medicine in the University of Bologna, but kept up his practice of medicine as well as devoting himself to his teaching and investigation at the University. His success at teaching is indicated by the fact that he was soon called to the University of Piza. Here he became associated with Borelli who was his senior by 20 years. Borelli assisted in many ways in aiding Malpighi to begin a successful scientific career. After three years, he left Piza because of unsuitable climatic conditions and returned to teach again at Bologna. Here he devoted himself to the study of minute anatomy, but shortly afterwards was called to a professorship at Messina at a good salary. Four years later he again returned to Bologna where he was active in teaching and investigation for 25 years. In 1691, when in his 64th year, he went to Rome as private physician to the Pope, but being in failing health died of apoplexy three years later.

In spite of a good deal of friction and jealousy aroused by certain enemies, Malpighi received recognition and numerous honors both at home and abroad. These honors included his election as Fellow of the

Royal Society of London, an honor which he repaid with his portrait, numerous communications, and his original drawings illustrating the anatomy of the silkworm and the development of the chick.

With respect to his scientific discoveries Malpighi made important contributions to several distinct fields of biology. His work in physiological anatomy involved a microscopic study of tissues for the purpose of explaining their anatomy. In 1660 he demonstrated the structure of the lungs, basing his work particularly upon the lung of the frog. In this connection he actually saw the movement of blood through the capillaries of the transparent wall of the lung.

Malpighi also discovered the intermediate, mucous layer of skin which bears his name. He made extensive observations upon the structure of glands. He worked out and published a "Monograph on the Structure and Metamorphosis of the Silkworm" which is a landmark in work of its kind.

In the period 1675-79, he brought out his "Anatomy of Plants," one of his best and most extensive works. A quartor edition of this work contained 162 pages and was illustrated by 93 plates of figures. In this work the author describes in considerable detail the microscopic structure of the bark, stem, roots, and seeds. He also includes a discussion of germination and a treatise on galls. By this contribution, Malpighi has earned a share in the title of "fathers of plant anatomy," a distinction which he divides with the English physician Nehemiah Grew.

In conclusion, permit me to contrast the points of view represented by the three men discussed. Hooke and Leeuwenhoek were inventors who developed their microscopes to a certain degree of perfection and then proceeded to use them upon whatever came to hand. These they observed, drew, and described as accurately as they were able. For them the emphasis was upon as wide a search as possible for materials which could be exploited by their microscopes.

Malpighi, and also Grew and Swammerdam not discussed in this paper, were biologists whose chief interests were living organisms. The microscope to them, therefore, was but a tool with which to elucidate the structures of animals and plants so that a clearer understanding could be gained of these organisms. It is perhaps needless to add that both types of individuals have made valuable contributions to microscopy, since the improvement of equipment and the execution of preliminary exploratory studies are necessary for the advancement of more purposeful research.

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William Ephraim Heal, Indiana Pioneer Mathematician

Will E. Edington, DePauw University

Serious research study in mathematics in the United States did not really begin until after the founding of Johns Hopkins University in 1876, and the first non-honorary Master's degree in mathematics in Indiana appears to have been given to Joseph Swain, at Indiana University, in 1885. There were very few professional mathematicians in Indiana before 1890, and such as were here were born in other states than Indiana. Several resident Indiana mathematicians published research before 1900, among them Henry Turner Eddy, Clarence Abiathar Waldo, Arthur Stafford Hathaway, and Robert Judson Aley, but the first native born Indianan to publish research was, so far as I have been able to find, William Ephraim Heal, a native of Grant County, whose first paper appeared in the Annals of Mathematics in 1886.

William Ephraim Heal was born May 17, 1856, in Grant County, and his first ten years were spent on a farm. His family then moved to Delaware County but returned to Grant County in 1878. In that same year he was married to Miss Nancy E. Parrill, daughter of a farmer, William Parrill, who lived near New Cumberland. Heal by then had completed his formal education in the public schools and the county Normal School. In August, 1880, he moved to Marion, the Grant County-seat, and began clerking in a grocery store. A little later he became a deputy in the Clerk's office and held this position for two and a half years, and then accepted a position in the George N. Winchell store as bookkeeper. A year later he took a position in a Marion bank, and in 1885 he became deputy county treasurer. He was elected County Treasurer of Grant County in 1892, taking office August 12, 1893, and serving for the next two years. During this period he was active in civic affairs in Marion, and was one of the signers of the Articles of Incorporation of the Y.M.C.A., organized in Marion, May 19, 1891.

In 1902 Heal was asked by a group of men in Marion who were financially interested in the Coffeyville, Kansas, Glass Factory, to make an audit of the company's books. He stayed in Coffeyville until 1908 and then took up independent auditing, mostly municipal books, in various parts of the country. In 1910 he entered the Government service in Washington, D. C., doing efficiency accounting and later becoming a Computer in the Bureau of Plant Industry. He later was with the U. S. Coast and Geodetic Survey and remained there until his sudden death by heart attack on October 9, 1925, at the age of sixty-nine. Such are the principal details of the professional life of this pioneer outstanding Indiana mathematician.

From the study of his educational training and his professional life it is evident that none of it was particularly conducive to his mathematical development. In a brief biographical sketch which appeared, together with a photograph of him, in a Souvenir Magazine Section, issued in 1892 by the Daily and Weekly Leader, of Marion, Marvelous Marion, the Queen City of the Gas Belt, 1893, occurs the statement: He secured his education in the "common and normal schools of the county and hence had superior advantages, but he early manifested a great liking for mathematics and astronomy, and it is in the former of these especially, that he shows his peculiar abilities. He took up and naturally and easily mastered the problems of Mathematical Astronomy, on to Analytical Geometry and the higher plane curves." That he possessed considerable innate mathematical power and ability is readily recognized when one realizes that he published at a time when America had only the American Journal of Mathematics, founded in 1878, and the Annals of Mathematics, founded in 1884, as vehicles for the publication of mathematical articles. His earliest publication was a problem and solution in the Annals of Mathematics, Vol. 2, Feb., 1886. In August, 1886, in this same volume appeared his first paper, so far as I can find, entitled "Expression of the Coefficients of Sturm's Functions as Determinants." He continued to propose problems and send in solutions to the Annals for several years. His second paper, "Some Properties of Repetends," appeared in Vol. 3 of the Annals, August, 1887, and in Vol. 4, April, 1888, he published "On Certain Singularities of the Hessians of the Cubic and the Quartic." In Vol. 5, October, 1889, pp. 33-41, appeared "The Bitangents of the Cubic," and in this same volume, pp. 109-110, is published a personal letter written to Heal by Professor Arthur Cayley, of Cambridge, England, in which Cayley, in reply to letter written by Heal to Cayley, recognizes the value of Heal's results and offers suggestions that will reduce his solutions to form found in Salmon's Higher Plane Curves. This was followed by the publication in the Annals, Vol. 6, Oct., 1891, pp. 64-68, of what is probably Heal's outstanding contribution during this period, a paper on "The Bitangential of the Quintic." This paper appeared in several leading scientific journals, among them The Proceedings of the London Mathematical Society.

That Heal enjoyed a certain national reputation is made evident by the fact that he was elected to membership in The New York Mathematical Society, in April, 1891, he being one of the first four mathematicians in Indiana elected at that time, the others being Henry T. Eddy, President of the Rose Polytechnic Institute, Clarence A. Waldo, at that time Professor of Mathematics at DePauw, and Joseph Swain, Professor of Mathematics at Indiana University. Swain went to Stanford with David Starr Jordan in the Fall of 1891 and returned to Indiana University in 1893 to become its president. Five other Indiana mathematicians were elected to the Society later in the year 1891, Robert J. Aley, Rufus L. Green, Arthur S. Hathaway, Moses Stevens and Alexander Knisely. The New York Mathematical Society was organized in November, 1888, at Columbia University, first as a local club, and did not become really national in its membership scope until 1891. It became the American Mathematical Society in 1894. In May of 1892 Heal was elected a member of the London Mathematical Society.

The American Mathematical Monthly was founded by Benjamin Finkel in 1894 and Heal published several papers in it shortly after its appearance: "Quadrature of the Circle," Vol. 3, p. 41; "Some Divisibility Tests," Vol. 4, p. 171; "Expression of Riemann's P Function as a Definite

Integral," Vol. 7, p. 155. Following this last publication, Heal moved to Kansas and I have not found that he published anything more in mathematics until in 1917 and 1918 when he discussed the demonstration of a geometrical theorem in the Monthly. Also when he went to Kansas it appears that he allowed his membership in the American Mathematical Society to lapse.

Mr. Heal became a member of the Mathematical Association of America in 1917 shortly after its organization in 1916, and he renewed his membership in the American Mathematical Society in 1919. He attended the Maryland-Virginia-District of Columbia Section meetings of the Association in May, 1921, December, 1921, May, 1922, May, 1924, and December, 1924, and he gave a paper on "Fermat's Last Theorem," at the May, 1921, meeting. But I do not find any reference to his further publication on anything in mathematics.

Following the receipt of the notice of Mr. Heal's death in 1925, W. D. Cairns, Secretary of The Mathematical Association of America, wrote to Mr. Heal's son: "I am very sorry indeed to hear of the death of your father. I recall how courteous he was at the Washington meeting last December when he made it a point to hunt us up at our hotel as officers of the Association and greet us before the meeting began."

Some years after Mr. Heal's death his mathematical library of some 155 volumes was given, in 1931, to the Tulsa, Oklahoma, Public Library, where it was arranged in the Technical Department and is known as "The Heal Mathematical Collection." It is a representative collection of volumes of Heal's time in the fields of advanced geometry, number theory, and the Philosophy of Mathematics.

From the preceding study it is evident that William Ephraim Heal was the first resident native born Hoosier to attain national distinction as a mathematician. That he possessed unusual mathematical talent, as compared with his fellow American contemporaries, cannot be denied. One can but wonder what he would have been able to accomplish in mathematics had he been privileged to study abroad and to develop his talent to its fullest.

PHYSICS

Chairman: Arnim Hummel, Ball State Teachers' College

R. E. Winn, Purdue University, was elected chairman for 1953

ABSTRACTS

Nuclear Spectra—A Survey. Allan C. G. Mitchell, Indiana University.[1]—The general methods of measuring radiations emitted by the nucleus, namely, beta rays and gamma rays, are discussed. Various magnetic spectrometers are described. The examples of the type of results obtained showing energy level schemes and methods of determining spins and parities are presented.

Nuclear Spectra of Rb^{82} and Rb^{84}. Charles M. Huddleston and Allan C. G. Mitchell, Indiana University.[1]—The nuclear spectra of Rb^{82} (6.3 hr) and Rb^{84} (34 day) have been measured with a magnetic lens spectrometer. Rb^{82} emits two positron groups of energies 0.775 and 0.175 Mev. It also decays by orbital electron capture. A large number of gamma-rays accompanies the disintegration. Reasonable agreement with the gamma-rays emitted by Br^{82} has been obtained. Rb^{84} emits three groups of positrons having end-point energies of 1.629, 0.822, and 0.373 Mev. One gamma-ray whose energy is 0.890 Mev has been found. Level diagrams for these disintegrations will be discussed.

The Isomer Rb^{84m}. R. S. Caird and Allan C. G. Mitchell, Indiana University.[1]—With the help of scintillation counters information on the isomer Rb^{84m} has been obtained. The isomer was produced by an (n, 2n) bombardment of ordinary Rb salts. The half-life has been determined as 21 min. Three gamma-rays have been observed at 0.239, 0.463, and 0.890 Mev. The last gamma-ray occurs in the product Kr^{84}. Coincidence measurements show coincidences between the gamma-ray at 0.239 Mev and another of nearly the same energy, while coincidences between the 0.463 and the gamma-rays at 0.239 Mev are essentially negligible. A possible level scheme will be discussed.

The energy dependence of the differential scattering cross section of alpha particles on helium. Frederick E. Steigert, Indiana University.[1]—The differential cross section for the elastic scattering of alpha particles on helium is measured at 21.0, 19.6, 18.3, 16.6, 14.9, and 12.9 Mev, using Kodak NTA emulsions to observe the reaction particles. The angular distributions observed show marked dependence on the incident energy, exhibiting a double minimum at the highest, going through a broad shallow single minimum at intermediate values. This minimum becomes continually narrower and deeper with lower energies.

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[1] Supported by the joint program of the ONR and AEC.

Longitudinal vibrations in a hollow metal tube. Earl Martin, Hanover College.—When a large gun tube is fired there are vibrations set up in it the nature and frequency of which have hitherto been unexplained. An attempt is made to give this explanation. The effect of these waves has been photographed and their existence has been verified for some time after the disturbance has taken place.

On the theory of bridge transfer in electric contacts. Frank J. Spayth, P. R. Mallory and Co.—A critical resumé of the various existing theories of bridge transfer in electrical contacts is presented. These theories are evaluated in terms of the existing data. New data on low voltage bridge phenomena is presented with reference to its possible influence on the negative transfer of metal. Some basic experiments needed for a more complete evaluation of the problem will be described.

The structure of the $4s^2nf^2F$-terms of ionized Germanium GeII. K. W. Meissner and K. L. Andrew, Purdue University and Friends University.—The employment of interferometric wavelength measurements of certain germanium spark lines made it possible to determine the fine structure of a few $4s^2nf^2F$—-terms of GeII. All the terms for $n = 4, 5, 6,$ and 7 exhibit inverted term order and the splittings range from 0.47 to 0.75 cm^{-1}.

PSYCHOLOGY

Chairman: L. M. Baker, Purdue University
Chairman for 1953 to be announced later

ABSTRACTS

University teachers self-perceived dynamics of effective teaching. Paul C. Baker and H. H. Remmers, Purdue University.—The instrument used in this study was a 70 multiple-choice item questionnaire designed to elicit responses to four general questions: (1) What is being done in your department to help you become a more effective teacher? (2) What are you doing to become a more effective teacher? (3) What are the most serious hindrances to effective teaching? (4) What is your philosophy of Education?

The questionnaire was circulated among the faculty of Purdue University with instructions to answer each question by choosing one of the alternate answers, and then to rank the items in each section in order of their importance as contributors to effective teaching. Of the questionnaires returned, 257 were complete and were used in the statistical analysis.

Each of the two responses to every question was examined separately. By analysis of variance, statistically significant variations were identified among groups of respondents of (1) different schools and departments, (2) different academic ranks, and (3) different academic degrees. When viewed in the light of known facts of departmental differences, these variations give strong support to the validity of the results obtained.

The respondents, as a group, feel that among the most important contributors to the achievement of teaching effectiveness are: (1) Constant experimentation with new and different teaching methods. (2) Keeping abreast of recent developments by constant reading of their respective literatures. (3) Advanced research. (4) Staff meetings where teaching problems are discussed.

Among the things felt not to be important are: (1) Use of the Purdue Rating Scale for Instruction to gauge student reaction to teaching. (2) Class visitation by a peer. (3) Consultation with the dean or department head on teaching problems.

The most serious hindrances to effective teaching are felt to be: (1) Bad physical conditions in the classroom and office. (2) Lack of emphasis upon research. (3) Poor sectioning of students. (4) Time wasted with trivial and routine matters. (5) Lack of recognition for superior teaching.

A factor analytic investigation of some aspects of the social behavior of Schizophrenics. Harry W. Blair, Beatty Memorial Hospital.—A diversity of conceptual treatment of the observations of social impairment in schizophrenia suggests a need for a common set of concepts which will facilitate further systematic exploration in this area. Among the various methodological alternatives to which a clinical psychologist may resort, factor analysis offers many advantages.

The present investigation dealt with a variety of behavioral observations in an interview situation which seemed to be of social import. After rough scaling and later reduction to dichotomous categories for the computation of tetrachoric correlations, factors were extracted by the multiple-group method. Data was obtained from 100 schizophrenic patients who were later compared on factor loading indices with 40 non-schizophrenic patients. Factor loadings for case history variables were also obtained.

Of the six oblique factors obtained, a highly related triad of factors evolved into a more general factor of social ability. These three related factors were named: General social orientation and capacity, Socio-motoric responsiveness, and Reactive assertion and reproduction. Differences between non-schizophrenics and the various schizophrenic subtypes as to factor loading indices were highly significant, as were many of the comparisons among schizophrenic subtypes.

The entire investigation is viewed as exploratory and the relationships observed are regarded as tentative, despite a circumscribed demonstration of their descriptive usefulness.

The effects of moving on various factors of adjustment. N. M. DOWNIE, Purdue University.—This study was made in a community in the Pacific Northwest. In some classes nineteen out of twenty-five children had attended schools other than the local ones. Academic ability, as measured by the Otis Self Administering Test of Mental Ability, and social adjustment, as measured by a sociometric device, were studied.

In 1949, all children in 18 classes making up grades five through eight were given the Otis test. Also during the first three months of school, before various activities began, each child was asked to name three other children with whom he would like to carry out each activity. Twelve such questions were given each student.

An analysis of the intelligence test scores on the basis of number of schools attended showed no differences in the mean score of the different groups. Social acceptance, as measured by the sociometric device, showed rather confused results. Children with one or two moves or who were in the school system from one to three years after moving had better social acceptance scores than those who had always been in the local schools, those who had moved around quite a bit, or those who had been in the local schools less than one year.

A study of personal data as predictors of the job behavior of telephone operators. N. FRIEDMAN and E. J. MCCORMICK, Purdue University.—Studies in several situations have indicated that personal data are predictive of employee job behavior. This study was concerned with examining the relationship between personal data and tenure with view toward reducing turnover by scientifically determined selection procedures.

The predictors were biographical items called from the application blanks of 336 telephone operators from one large exchange. Further, 254 of these operators were rated by three supervisory personnel on over-all job performance. These ratings were intended to serve as an ultimate check on recommended selection procedures.

Analysis with a primary group indicated that four items were related to tenure. An item selection technique, developed for this study, when applied to the holdout group, indicated that two of these four items afforded maximum prediction of the criterion. The two items were education and marital status. An analysis of variance was run for the job performance ratings of operators in each of six combined marital status and education categories. The results of these analyses suggest the following conclusions:

1. That hiring single applicants with a high school education (or preferably less) would decrease turnover.
2. That operators selected on the basis of the tenure analysis would not differ significantly in over-all job performance from the total operator population.

An analysis of nine personality scales. FRANK S. MCKENNA, DePauw University.—A battery of nine personality scales composed of the Allport A-S Reaction Study, abridgments of Gulford's scales of Cycloid Emotionality and Rhathymia from An Inventory of the Factors STDCR, and the six Heston Personal Adjustment Inventory scales of Analytical Thinking, Sociability, Emotional Stability, Confidence, Personal Relations, and Home Satisfaction were administered to 235 college sophomores. Scale intercorrelations were calculated and three factors were extracted utilizing Thurstone's centroid analysis. Orthogonal rotations of the reference axes were performed to give simple structure. Multiple regression equations were derived to predict factor scores on the basis of scale scores, and the score of each of the 235 subjects was predicted for each of the three factors. The highest and lowest 27 per cent of subjects in each factor score were identified and an item analysis of the 270 Heston items was performed, utilizing Flanagan's table of correlation coefficients.

On the basis of the factor loadings of the scales and items the three factors were tentatively identified as representing the bipolar personality traits of: (1) Relaxed Emotional Stability vs. Anxiety-Depression, (2) Rhathymic Extroversion vs. Shyness, and (3) Confidence vs. Inferiority-Submissiveness. The similarity of these factors to those reported in previous investigations increases the confidence in their importance as common traits of personality.

Problems of a clinical psychologist in a prison situation. N. S. HOLLIS, Indiana State Farm.—All of the problems that are common to clinical psychologists are found in the prison situation also, for prisoners are human too. Also, the same methods—intelligence tests, diagnostic devices and therapies, etc.—are used in the prison laboratory as they are in "outside" situations. The personality disorders encountered by the prison psychologist are similar to those he meets in his private clients except that the conflicts of the prisoner are usually more severe.

Some of the problems are only remotely related to usual clinical practices. They include dealing with men seeking work transfer; those wanting their case reviewed; chronic complainers about food, work conditions, general treatment; those seeking a variety of special privileges; those requesting evaluation of "inspired" productions as poems, stories, pictures, music, hand-craft articles. There are a variety of "phonies" to be dealt with such as the religious reformers, lawyers, psychologists, hypnotists, some of whom have professional training but no adequate opportunity for usual practice and others who are posing. An over-all problem of great importance is trying to help men adjust in a situation that may be thought of as "abnormal" for each individual.

The testing of the intelligence of motor handicapped persons. EDWARD T. JORDAN, Indiana State Teachers' College.—1. The nature of the problem. Brain injuries, Cerebral Palsies, Vascular Insults, all have effects on the sensory and motor abilities of the persons suffering them.

Where the receptor organs are damaged and the motor functioning also impaired the usual psychometric techniques cannot be validly employed, owing to their large dependence on verbal expression, motor performance, or written responses.

Performance Tests have been relied upon in purely sensory involvements, where the motor capacity has been reasonably intact, but where the sensory and motor capacities are reduced at the same time, the response disability renders the test program, if using parts of the standard tests, quite invalid.

2. A possible solution. To overcome this difficulty tests have been conducted with cerebral palsy cases, post-cerebral trauma cases, and others, to discover methods of assessing intelligence, and the level of educability, independently of speech, writing, or motor performance abilities.

Perceptual intelligence was selected as the sole remaining avenue of impression with techniques involving the ability to produce a "Gestalt," by completion of the elements visually presented, and in keeping with Spearman's "Laws of Noegenesis," to determine the ability to perceive the relationships presented and educe the missing correlates in a given presentation.

A description of a tentative scale, with two forms for the pre- and post-grade school levels, which is the subject of research by the author, was given.

Attitudes toward public education, as related to n variables. R. BRUCE KIRK.—To investigate the relationships between the attitudes of high school students and those of adults toward the public school system, and also the interrelationships of the attitudes of the students, a questionnaire which had appeared in Life Magazine was adapted for high school students.

From a total of over 8,000 students throughout the country in schools which participate in the Purdue Opinion Panel, a sample of 2353 was selected, chosen randomly on all categories except grade and geographical region, these being stratified.

Chi-square tests revealed general agreement between the attitudes of students and those of adults toward the public school system. Significant differences were found between sub-groups of students when they were divided on the basis of their sex, grade in school, rural or urban residence, religion, socio-economic status, political party, geographical region in the United States and mother's education. Most differences were found between students whose political party preferences were different, least between those whose mother's education levels were different. The items of the questionnaire were tested and it was found that the questions which were most discriminating were those regarding Federal aid to parochial schools, some free college education for all who want it and the pay of teachers.

These results are believed to have implications for the schools and for designers of curricula.

A validation study of intropunitive and extrapunitive signs on the Rorschach Test, based upon records given by suicidal and homicidal subjects. CAROLYN PRATT, V. A. Hospital, Indianapolis.—The present study is an attempt to validate those constellations of factors on the Rorschach Test which are interpreted as intropunitive and extrapunitive by quantitative and qualitative analyses of the protocols given by persons who have attempted to commit suicide and/or homicide. The experimental populations included 51 subjects who had attempted or committed suicide, and 48 subjects who had attempted or committed homicide. Wechsler-Bellevue IQs were available for 29 homicides, mean IQ 91, and for 29 suicides, mean IQ 108, a difference significant between 1% and 2% level of confidence, using the t test of significance.

When the two groups were compared by chi square with Beck's norms, they were found to differ statistically to a significant degree in many respects. When the experimental groups were compared with one another differences were found but interesting similarities were also noted.

Possibly the most significant findings were the result of an intensive analysis and comparison of the 12 most serious suicidal records with 12 less serious suicidal records and 12 random homicidal records. As a result of this comparison, it was suggested that the typical serious suicidal patient of this population was an individual of above-average IQ, whose Rorschach protocol showed a high number of responses, extratensive experience balance, emotional instability (high CF), inability to relate to others affectively (low FC), inability to appraise himself objectively (low V), marked dysphoria and anxiety (high Y), and aggressive trends (high S). His maladjustments were more likely to be expressed in significant content than by rejecting the cards. On the other hand, the less serious suicidal patient of this population was a person of about average intelligence who displayed an hysterical Rorschach pattern with low R, constriction of M, CF, FC, V, Y, and S, with a high rate of card rejection. The typical homicide of this population was a person of below-average intelligence whose record resembled that of the less serious suicide except in a higher number of Y responses.

ZOOLOGY

Chairman: F. R. Elliott, Valparaiso University

W. H. Johnson, Wabash College, was elected chairman for 1953.

ABSTRACTS

An Indiana microsporidian parasitic on Drosophila. Robert L. Bell, U. S. Army.—In the latter part of 1950 a Drosophila (wild-type) culture was prepared using the bloom from a water lily (yellow variety) in the culture medium. The bloom came from George Lake near Hobart, Indiana, and seems to be indicated as the vector of the Nosema-like disease which became prominent later. The legs of the infected individuals are pale in color and seem more fragile than the normal individual's, the abdomen is also pale in color as well as being somewhat swollen. The general character of the infected individual is a languid one, the individuals often remaining motionless for long periods of time.

The infecting organism, in no case observed more than 10 micra long, was found generally distributed throughout the tissues. A few individuals with pseudopod-like projections were observed; but, the presence of a discrete amebula stage seems contraindicated. Internal differentiation is strongly demonstrated upon proper staining of the fixed organism. Pansporoblasts were not observed as such; but, at least one individual with the same physiological function was observed. The rapid growth of these organisms in the host seems to produce a functional castration; since, even though there may be many imagoes in a culture there may be just a few or no larvae at all.

Regression and replacement of hydranths in *Obelia* and *Campanularia*. Sears Crowell, Indiana University.—Actively growing colonies of *Campanularia flexuosa* have been observed for several weeks and the history of each hydranth has been recorded. After only a few days' existance a hydranth loses its form and its substance is resorbed by the colony as a whole. In about a day a new hydranth develops on the pedicel of the one which had undergone regression. Thus, though a colony may be old, its hydranths are always young. A hydranth has an average life span of only 3.8 days at 21°C. and of 6.8 days at 17°C. The regression is a regular and cyclic phenomenon. Older hydranths regress before younger ones. In a colony about 15% of the hydranths are at some stage of the regression-replacement process. Under unfavorable conditions the per cent is higher.

The regression of hydranths in *Obelia* and *Campanularia* was well described long ago (Loeb, Huxley and DeBeer, and others), but only Hammett has believed it to be a naturally occurring and endogenous phenomenon. However he did not follow the history of identified hydranths.

These suggestions may be made as to the significance of the regression-replacement process: The resorption following dedifferentiation insures that there is no loss of substance by the colony except for the hydrothecae. The senesence of the colony is avoided by the replacement of its older members by new hydranths. The feeding parts of a colony are kept clear of attaching organisms by the frequent shedding of the hydrothecae.

An investigation of marine trematodes in Puerto Rico. R. M. CABLE, Purdue University.—In an eleven-month study of larval and adult stages of marine trematodes in Puerto Rico, 51 species of cercariae were found and the life cycles of several of these were determined. The number of adult trematodes found will not be known until the collection can be studied in detail. Although effort was concentrated on those occurring in fishes, some attention was given to birds after finding trematode larvae expected to have their adult stages in avian hosts. This paper, preliminary in nature, is a general report dealing largely with the locale including both the island of Puerto Rico and Mona Island which was visited twice.

Some unusual cases of arthropod infestation. WILLIAM HUGH HEADLEE, Indiana University Medical Center.—Our parasitology laboratory has been requested frequently to identify specimens pertaining to medical entomology, these being suspected of influencing the mental or physical well-being of individuals, in some real or fanciful way. A wide variety of arthropod species have been examined and histories secured concerning their relationship to a specific medical problem. Some cases were of interest because of the infesting organism, per se, while others were of interest because of the peculiar circumstances of the case and the incriminations made prior to detection and/or the correct specific identification of the arthropod.

In one instance, the dermatitis caused by flea bites led to a mistaken primary diagnosis of chickenpox. Squirrels living in the attic were the source of the fleas. In another instance, the cause of an unusual case of dermatitis was found to be the bites of the bedbug, *Cimex lectularius*, harbored in a wicker chair. In a third case, suspicions of possible attempted "arsenic poisoning" were finally allayed when the white particles in sandwiches (served in the cafeteria at an important war-time industrial plant) were identified as fly eggs. The larvae that hatched from these eggs were identified as those of *Lucilia sericata*. Perhaps of most import was the finding and identification of the grain itch mite, *Pediculoides ventricosus*, by the writer in October of 1950, in straw brought to him from an Indiana industrial concern which was using straw in its manufacturing process. This mite had appeared in great numbers for the first time in several decades, and was causing incapacitating dermatitis among persons working with straw. Visitors and workers at the Indiana State Fairgrounds were plagued with these same mites in 1950 and 1951, which were found and identified in straw being used in the barns as bedding.

The Araneology of Indiana

F. R. Elliott, Valparaiso University

The aim of the present paper is two-fold. First to list the literature pertaining to the Araneology of Indiana, accompanying the same with a brief description of the nature and content of each work, and second to revise the list of known spiders of Indiana to include all species identified since the last revision (Elliott) in 1931.

I. The Literature

The literature pertaining to the Indiana araneae (spiders) is exceedingly scattered in different publications and no resumé has been prepared that will at once put in the possession of the student the always welcome information regarding the status of the subject.

Recorded observations on spiders of the North American fauna had been made as early as 1800. Bosc left an unpublished manuscript and a list of 25 species of spiders collected in North Carolina. Thomas Abbot had prepared a series of illustrations of Georgian spiders accompanied by a manuscript of notes and observations on the drawings of spiders of Georgia. The list of spiders of Bosc was published by Baron Walckenaer in 1805 and descriptions and notes of both Bosc and Abbot were included in Walckenaer's "Apteres" published in 1835. Nicholas Marcellus Hentz began his studies of spiders in 1821 and his publications in the Journal of the Boston Society of Natural History to 1867 included 250 species of spiders of which 199 were from the southern states, chiefly North Carolina and Alabama.

Although much progress had been made in American araneology and a large number of species had been described, these were principally from southern states, hence the paper by Dr. Thorell in 1877 on the araneae collected in Colorado in 1875 by A. S. Packard was almost the first west of the Mississippi. This condition was to a considerable extent also true for Indiana, however, descriptions of a few spiders from this region had appeared some years earlier. The Araneology of Indiana had its beginnings in the work of Hentz in 1847 with the description of a single species, Agalena naevia. Since that time some 33 papers pertaining to the Araneology of Indiana have been published.

While it is not possible to classify the papers on the Araneology definitely on basis of the aspect of study they can be roughly grouped under three headings, biology, ecology and taxonomy as follows:

Biology

Moenkhaus, The spinning of the egg-sac in Lycosa; Petrunkevitch, The sense of sight in spiders; McIndoo, The biology of the Shawnee Cave spiders, and notes on some Arachnids from Ohio Valley Caves; Andrews, The digestion of a mouse by a Tarentula; Kintner, Some spiders of the genus tetragnatha; and Minton, Injuries of venomous animals in Indiana.

Ecology

Cope, The Wyandotte Cave and its fauna, and observations on Wyandotte Cave and its fauna; Emerton, Notes on the spiders from caves of Kentucky, Virginia and Indiana; Packard, The invertebrate cave fauna of Kentucky and adjoining states and The cave fauna of North America with remarks on the anatomy and origin of the blind species; Blatchley, Caves and their fauna; Banta, The fauna of Mayfields Cave; Elliott, An ecological study of the spiders of the beech-maple forest; Lowrie, The ecology of the spiders of the xeric dunelands in the Chicago area and the ecological succession of the spiders of the Chicago area dunes.

Taxonomy

Hentz, Descriptions and figures of araneids of the United States; Marx, Catalogue of the described araneae of temperate North America; Fox, A list of spiders from Indiana; Banks, A preliminary list of the Arachnida of Indiana with keys to families and genera, and a catalogue of nearctic spiders; Petrunkevitch, Synonymic Index—Catalogue of spiders of North, Central and South America with all adjacent islands, Systema Aranearum, and Catalogue of American spiders Part 1; Comstock, The Spider Book; Wenninger, Notes on Miranda; and Elliott, Revision and additions to the list of Araneae of Indiana.

As is evident from the above titles the greater part of the literature on spiders of Indiana deals with the identification of the species. Of the papers listed biology, those of McIndoo and Kintner devote considerable attention to structural features and determination of species. Of the papers listed ecology each, in addition to description of the ecological relations, includes taxonomic material and lists the species of spiders.

A brief characterization of the papers follows.

Hentz—Descriptions and Figures of the Araneae of the United States, 1847, describes one species Agelena naevia, 1850, describes four species, Micrathena sagittata (Epeira spinea), Micrathena gracilis (Epeira rugosa), Theridion tepidarorum (Theridion vulgare) and Enoplognatha marmorata (Theridion marmoratus), 1867, describes one species, Dendryphantes tripunctatus (Attus tripunctatus). All species are from Indianapolis but collector is not named.

Cope (1872) and (1878) Wyandotte Cave and its fauna and observations on Wyandotte Cave and its fauna.

This paper was published in 1872 and a revision of same in the Indiana State Geological Report in 1878. However no change was made with reference to the fauna. The author reports collection of 16 species of animals, one being a true spider which due to impurity of the preserving fluid was destroyed hence not identified.

Emerton (1875) Spiders from caves of Kentucky, Virginia and Indiana.

The spiders collected by A. S. Packard consisted of specimens comprising eleven species, three being from Indiana caves. They were Nesticus carteri, Phanetta subterranea (Linyphia subterranea) and Meta menardi.

Packard (1875) The invertebrate cave fauna of Kentucky and adjoining states. (1886) The cave fauna of North America.

Specimens of the fauna were observed and collected from Wyandotte, Bradford, Connely, Buzzard, Blue Spring and Donnelsons caves. The spiders from these collections were identified and described by Emerton in the previous paper. The cave fauna was extended culminating in the paper, cave fauna of North America. Notes from descriptions of the spiders were incorporated therein and one or two observations made by Packard. However no additional species were described.

Marx (1889) Catalogue of described Araneae of Temperate North America.

The author lists eight spiders for Indiana and records the source of the description of each. These are Castaneria trilineata (Thargala lineata), Nesticus carteri, Linyphia weyeri, Antrobia mammouthia, Troglophantes cavernicolus (Willibaldi cavernicola), Phanetta subterranea, Micrathena sp. (Acrosoma sp.) and Lycosa nidicola.

Fox (1892) A list of spiders from Indiana.

The list of spiders was from a collection of Frederick Test sent for identification. The paper was presented at a meeting of Washington Entomological Society. Fox states, "My reason for presenting them to the Society is that they are from a locality that has never been collected in before." The list includes 77 species. These are identified by the letter F. in the list of Indiana Spiders included herein.

Blatchley (1896) Indiana caves and their fauna.

This includes faunal collections from nineteen of the most important caves of Indiana. It consists of discussion of the formation of caves, short description of each cave, descriptions of new species found, notes on occurence, habits, and inter-relations of the various cave animals. The spiders are enumerated for each cave. The list includes seven species as follows: Tegenaria cavicola, Meta menardi, Dolomedes urinator, Theridion porteri, Tmeticus tridentatus, Nesticus carteri, and Phanetta subterranea.

Moenkhaus (1901) Spinning of the egg-sac in Lycosa.

The paper discusses the manner of construction of the egg-sac, the laying of the eggs and the enclosure of the egg-sac within the cocoon. The entire process takes place in a little more than a half hour. In the process the sheet-like web upon which the eggs are laid is cut loose and rolled up with the mandibles and palpi. This edge appears as a rather prominent equatorial band around the cocoon at the line of attachment of the sheet. The author states that examination of the egg-sac of more than fifty species of Lycosidae shows an equatorial band hence it would seem that all the species adopt in general the same plan of constructing the egg-sac.

Banks (1906) Preliminary list of the Arachnidae of Indiana.

The material was collected by Blatchley and his assistants, also spiders from Professor Moenkhaus, Banta and Dr. Mel Cook. The paper includes a table for the families and a key to the genera represented. It also gives reference to the description of the species. The list includes the names of 148 species, the collectors and localities.

Petrunkevitch (1906) The Sense of Sight in Spiders.

This was read by title only at the Indiana Academy of Science and was revised and published elsewhere later. It discusses briefly the structure and type of eyes, light and dark adaptations, etc.

Banta (1907) The Fauna of Mayfields Cave.

This paper is the result of an attempt at a detailed study of the fauna of a small cave, observing its inhabitants throughout the year and in all conditions to which they are normally subjected. Temperature and air currents were observed, collections made, habitats noted, life histories worked out, etc. Some species were added from Truitts and neighboring caves. Seventeen species of spiders were identified and their distribution noted. The species are not listed here but may readily be determined by the designation Ba in the List of Spiders of Indiana included in this paper.

Banks (1910) Catalogue of Neartic Spiders.

This lists five species of spiders as occurring in Indiana and gives reference to the Indiana State Geological Report containing the descriptions. All species had been previously reported.

McIndoo (1910) Biology of Shawnee Cave Spiders.

Two species of spiders were studied in detail as to habitat, locomotion, webs and snares, food, enemies, moulting habits, cocoon spinning, etc. The species were Troglophantes cavernicola (Willabaldi) and Meta menardi.

McIndoo (1911) Notes on some arachinids from Ohio Valley Caves.

This includes collections from Marengo, Spring, Wyandotte, Little Wyandotte, Seberts Well, and Salt Peter Caves in Indiana and Mammoth Cave in Kentucky. Five species of spiders were identified from Indiana caves and the abundance, habitat, distribution and reaction to light, etc., studied. The species were Linyphia weyeri, Phanetta subterranea, Meta menardi, Theridion porteri and Erigone infernalis.

Petrunkevitch (1911) A Synonymic Index—Catalogue of Spiders of North, Central and South America with all adjacent islands, Greenland, Bermuda, West Indies, Terra Del Fuego, Galapagos, etc.

This voluminous work consists of an extensive 1. Bibliography. 2. A list of species with synonyms and references. 3. An alphabetical index to synonyms. This catalogue lists 64 species of spiders as having been reported or described from Indiana. These had been reported previously in other papers so are not enumerated here.

Comstock (1912) The Spider Book.

An excellent general text book dealing with the spiders and near relatives, the external and internal anatomy of the spider, life cycle, egg laying, and the structure and spinning of the web, descriptions and illustrations of many species of spiders are included. This lists two species of spiders as occurring in Indiana. There are Geolycosa pikei and Tegenaria sp.

Wenninger (1921) Notes on Miranda aurantia.

This discusses the structural features, habits, habitats and general features of Miranda.

Petrunkevitch (1928) Systema Aranearum.

This work is an attempt, to group the genera of spiders in a natural system, to bring the knowledge of spiders up to date, and to facilitate further study. It includes a key to the families of recent spiders, keys to the sub-families, a list of the genera of recent spiders alphabetically arranged within each sub-family, an alphabetical list of synonyms of recent genera, and indices to the genera listed and to families.

Andrews (1929) The Digestion of a Mouse by a Tarentula.

Kept Tarentula two years feeding same a number of different animals as insects, etc. A very young mouse was put in the cage at 3:45 p. m. By 8 a. m. the next day the mouse had completely disappeared. A second larger mouse was introduced into the cage at 2 p. m. At 5:30 p. m. the Tarentula succeeded in striking the mouse which died within a minute. The spider did not offer to eat the mouse.

Elliott (1930) An Ecological Study of Spiders of the Beech-Maple Forest.

An eighty-acre beech-maple forest known as Lewis Woods near Richmond, Indiana, was selected for intensive observation and study of spiders. Collections were made every two weeks for 16 months. Investigation was conducted along three lines. 1. Taxonomic, with a view to collection and identification of spiders. 2. Quantitative, to learn the representation of each species in the area. 3. Ecological, including a study of the species as to habitat, distribution in same, migration, hibernation and annual and seasonal succession. The paper includes description of the forest, distribution within the habitat such as Ground, Herb, Shrub and Herb-Shrub species, specificity of the species for the association, and annual and seasonal succession, etc. Ninety-nine species of spiders were present in this area.

Elliott (1931) Revision and additions to the list of Araneae (spiders) of Indiana.

The paper includes 1. the enumeration of the species, 2. additions of known species to the list, and 3. a uniform arrangement of species in a system that most nearly represents the present knowledge of the group. The list of species given includes collector, names and localities. Seventy species were added to the list of 148 species reported by Banks (1906) giving a total of 218 known Indiana spiders.

Kintner (1934) Some Spiders of the Genus Tetragnatha.

The paper describes the tribe Tetragnatha as to habitat, body shape, legs, Chelicerae, and colors and position of the legs and body when at rest. Egg laying and cocoon formation were also observed. The paper reports six species of Tetragnatha, three of these for the first time in Indiana. The species reported are Tetragnatha elongata, Tetragnatha laboriosa, Tetragnatha extensa, Tetragnatha vermiformis, Eugnatha straminea (Tetragnatha straminea) and Tetragnatha pallidula.

Petrunkevitch (1939) Catalogue of American Spiders, Part 1.

This includes the first two sub-orders of spiders namely the Liphiostomorphae and the Mygalomorphae. The author had hoped, with the aid of collaborating specialists, to include the Arachnomorphae. Sub-orders I and II are represented in Indiana by only two species, Apostichus flavipes and Atypus milberti.

Wenninger (1939) Notes on Miranda.

The abstract only was presented at the meeting of the Indiana Academy of Science (1939). The peculiar position of the eyes, some prominences, some internal features, mating, egg laying and distribution of the nest are noted. The author states that Miranda is the name that should be used although at least 28 writers mention neither the genus nor the species.

Lowrie (1942) The ecology of the spiders of the xeric duneslands in the Chicago area and (1948) the ecological succession of spiders of the Chicago area dunes.

Much of the work, particularly of the first paper, was done in Illinois. The spiders present are represented in the more comprehensive list of the succeeding paper. In addition to collecting in the Indiana-Michigan dunes area, collections included the black oak and foredunes of Waukegan, the black oak dunes of Kankakee, the climax forests of Saugatuck, various woods in Michigan, and at Smith, Indiana.

The associes discussed are those of Cowles, namely, the beach, the foredune, the cottonwood dune, the pine, the black oak-white oak, and the beech-maple climax. Stratification, biotic factors, and physical factors as temperature, evaporation, soil moisture and light, are discussed. Tables list the spiders of the different areas, the number of species found and give an analysis of the herbaceous based upon one hundred sweep units and the number of specimens collected. A total of 170 species is reported for the dunes area of Indiana.

Minton (1950) Injuries by venomous animals in Indiana.

Of venomous animals only the spiders and snakes are represented in the midwest by potentially dangerous species. The black widow spider, Latrodectus mactans, is described as to, coloration and markings. distribution in Indiana and habitat. Report on cases of bite by the spider includes symptoms and methods of treatment.

II. Revision of the List of Spiders of Indiana

In this as in the revision by the writer (1931) the order of the Families and Genera is that given in the Systema Aranearum by Petrunkevitch (1928). The species name likewise, except that given after 1911, is the one given in the Synonymic Index-Catalogue (1911) by the same author. That new genera have been added and that many changes have been made in those already in use the writer is well aware, however since no subsequent Index-Catalogue of spiders, except the Catalogue of American Spiders Part 1 Petrunkevitch 1939 which includes the Sub-orders Liphistiomorphae and Mygalomorphae only, has been published, it is thought best to follow the arrangement above indicated rather than that of revisions of different families by various arachnologists.

In instances where a species has been given different names by different writers such names if synonyms are included in parenthesis following the Index-Catalogue name. Otherwise no attempt has been made to give a Synonymy. In some instances a spider is best known and is most frequently described by American students under such names. Confusion likely to result from the nomenclature here given is however compensated by advantages from adherence to the rule of priority.

The arrangement of the families and genera, as stated, is that of the Systema Aranearum, Petrunkevitch (1928). A classification of recent spiders to family, as per this work, precedes the list of species herein given. The three Sub-orders of the Order Araneae (Spiders) are represented in the present list as follows: Sub-order I Liphistiomorphae, spiders with segmented abdomen, none; Sub-order II Mygalomorphae, spiders with four lungs, Famity Ctenzidae one, Apostichus flavipes, and Family Atypidae one, Atypus nulberti; Sub-order III Arachnomorphae, spiders with two lungs, is represented by 301 species. Of the forty-six families comprising the Arachnomorphae eighteen are represented. The number of species ranges from 1 in four families to 41, 44 and 49 in the families Attidae, Linyphiidoe and Argiopidae respectively.

No localities or collectors are given for spiders reported for Indiana by general publications such as the Descriptions of spiders of the U. S. by Hentz, Catalogue of Spiders of the U. S. by Marx, The Spider Book by Comstock, The Catalogue of Spiders by Banks and Index-Catalogue and Systema Aranearum by Petrunkevitch since neither collector nor locality is indicated. Collectors' or authors' names and localities are indicated for the following: Fox, list of spiders of Indiana; Cope, Wyandotte Cave; Packard, cave fauna of North America; Blatchley, fauna of Indiana caves; Banks, spiders of Indiana; Banta, Mayfields Cave; McIndoo, Shawnee Cave and arachnids of Ohio Valley Caves; Elliott, spiders of beech-maple forest and Revisions and additions to the list of Indiana spiders; Kintner, some spiders of the genus tetragnatha; and Lowrie, ecological succession of spiders of Chicago area dunes. The collector or author, except where represented by a very small number of species, is indicated by the first letter or letters of the name.

The revision and additions to the list of spiders of Indiana, Elliott (1931), included 218 species. The present list is augmented by 87 species making a total of 303 known Indiana spiders.

CLASSIFICATION OF RECENT SPIDERS

(To Family Only)

Order ARANEAE

I—Sub-Order Liphistiomorphae

1. Family Liphistiidae

II—Sub-Order Mygalomorphae

First Branch Nelipoda

2. *Family Ctenizidae* 1
3. *Family Atypidae* 1
4. Family Migidae
5. Family Dipluridae
6. Family Paratropididae
7. Family Pycnothelidae

Second Branch Hypodemata

8. Family Barychelidae
9. Family Theraphosidae

III—Sub-Order Arachnomorphae

First Branch Tetrasticta

10. Family Hypochilidae
11. Family Filistatidae
12. *Family Dysderidae* 1
13. Family Oonopidae
14. Family Hadrotarsidae
15. Family Telemidae
16. Family Caponiidae

Second Branch Trionycha

17. Family Oecobiidae
18. Family Urocteidae
19. Family Psechridae
20. Family Tengellidae
21. *Family Amaurobidae* 3
22. *Family Agelenidae* 18
23. Family Hersiliidae
24. Family Zodariidae
25. Family Palpimanidae
26. Family Eresidae
27. *Family Pisauridae* 6
28. *Family Lycosidae* 30
29. *Family Oxyopidae* 1
30. Family Senoculidae
31. Family Leptonetidae
32. *Family Sicariidae* 1
33. *Family Dictynidae* 10
34. *Family Theridiidae* 26
35. *Family Pholcidae* 1
36. *Family Linyphiidae* 44
37. Family Archaeidae
38. *Family Uloboridae* 2
39. Family Dinopidae
40. *Family Argiopidae* 49
41. *Family Mimetidae* 2

Third Branch Dionycha

42. Family Zoropsidae
43. Family Acanthoctenidae
44. *Family Ctenidae* 1
45. *Family Drassidae* 13
46. Family Ammoxenidae
47. Family Prodidomidae
48. Family Homalonychidae
49. Family Sparassidae
50. Family Selenopidae
51. Family Platoridae
52. *Family Thomisidae* 31
53. Family Aphantochilidae
54. *Family Clubionidae* 21
55. *Family Attidae* 41

List of Spiders of Indiana

3. Atypidae
    1. *Aposticles flavipes*, Petrunkevitch.
       Petrunkevitch synonymic Index-Catalogue as for Ind.
    2. *Atypus milberti*, Walck.
       B. Wyandotte Cave, New Harmony, (Dransfield).

12. Dysderidae
    3. *Ariadna bicolor*, Hentz.
       B. Wyandotte Cave, Mitchell, Mecca; E. Richmond, Crooked Lake, Valparaiso; F. Lafayette.

21. Amaurobidae
    4. *Amaurobius americanus*, Em. *(Titanoeca americana*, Em.).
       E. Richmond, Dunes Park; L. Dunes Acres.
    5. *Amaurobius bennetti*, Blackwall. (Ciniflo bennetti, Blackwall).
       Ba. Mayfields Cave, Truitts Cave; E. Richmond, Crooked Lake; L. Smith.
    6. *Amaurobius ferox*, Walck.
       F. Lafayette.

22. Agelendiae
    7. *Agelena naevia*, Walck. *(Agelenopsis pennsylvanica*, Koch).
       B. Tippecanoe Lake, Vincennes, North Vernon, New Albany, Clear Lake, Greencastle, Huntingburg; E. Richmond, Crooked Lake, Nashville, Valparaiso; F. Lafayette; Hentz. Indianapolis; L. Dunes Acres, Smith.
    8. *Agelenopsis utahania*, Chamb. & Ivie.
       L. Ogden Dunes, Smith.
    9. *Cicurina arcuata*, Keys. *(Cicurina complicata*, Em.)
       B. Bass Lake; E. Richmond, Dunes Park; F. Lafayette.

10. *Cicurina brevis,* Em.
B. Bass Lake; E. Richmond, Dunes Park; L. Dunes Acres, Smith.

11. *Cicurina pallida,* Keys.
B. Bass Lake, Wyandotte Cave, Putnam County; Ba. Mayfield's Cave, Truitts Cave; E. Richmond; L. Smith.

12. *Coelotes hybridus,* Em.
E. Richmond.

13. *Coelotes longitarsus,* Em. (*Coelotes calcaratus,* Keys.).
B. New Harmony; E. Richmond; F. Lafayette.

14. *Coelotes montanus,* Em.
E. Richmond.

15. *Coras medicinalis,* Hentz. (*Coelotes medicinalis,* Em.).
B. Putnam County; E. Richmond; F. Lafayette.

16. *Coras juvenalis,* Keys.
L. Smith.

17. *Coras lamellosus,* Keys.
L. Ogden Dunes, Smith.

18. *Tegenaria cavicola,* B.
B. Salt Peter, Crawford County; Bl. Salt Peter Cave, Crawford County, McIndoo, Shawnee Cave.

19. *Tegenaria domestica,* Clerck. (*Tegenaria derhama,* Scopoli).
B. Wyandotte Cave, Greencastle; Ba. Mayfield's Cave, Twin Cave; E. Richmond, Crooked Lake, Valparaiso; F. Lafayette.

20. *Wadotes calcaratus,* Keys.
L. Smith.

21. *Neoantistea riparia radula,* Keys.
L. Smith.

22. *Hahnia agilis,* Keys.
E. Richmond, Crooked Lake.

23. *Hahnia cinera,* Em.
E. Richmond, Crooked Lake; L. Ogden Dunes.

24. *Hahnia radula,* Em.
E. Richmond.

27. Pisauridae

25. *Pisaurina brevipes,* Em.
L. Smith.

26. *Pisaurina mira,* Walck. (*Pisaurina undata,* B.)
B. Arlington, Bass Lake, Shoals, Culver, Greencastle, Huntingburg; E. Richmond, Crooked Lake, Valparaiso, Nashville, Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.

27. *Pisaurina subinflata,* Henta.
B. New Harmony, North Vernon.

28. *Dolomedes tenebrosus,* Hentz. (*Dolomedes striatus,* Becker) (*Dolomedes scriptus,* Hentz).
B. Wyandotte Cave, Bass Lake, Mitchell, Medora, Cypress Swamp, Knox County, Lake Maxinkuckee, Gibson County, Wilders, Greencastle; Ba. Mayfield's Cave; E. Richmond, Crooked Lake, Valparaiso, Nashville, Dunes Park; F. Lafayette; L. Dunes Acres, Smith.

29. *Dolomedes triton sexpunctatus,* Walck. (*Dolomedes sexpunctatus,* Hentz).
B. Tippecanoe Lake, Greencastle; F. Lafayette; L. Dunes Acres.

30. *Dolomedes urinator,* Hentz.
B. Mitchell, Donnelson's Cave; Bl. Donnelson's Cave.

28. Lycosidae

31. *Allocosa funere,* Hentz.
B. Knox County; E. Richmond.

32. *Arctosa cinerea,* Fabricus (*Trochosa cinerea,* Fabricus) (*Arctosa litteralis,* Hentz).
B. Hammond, Grand Chain, Pine, Greencastle; L. Dunes Acres, Ogden Dunes, Miller.

33. *Arctosa rubicanda,* Keys. (*Lycosa polita,* Em.)
F. Lafayette.

34. *Geolycosa fatifera,* Hentz (*Lycosa fatifera,* Hentz).
B. Wyandotte Cave, New Harmony, Culver, Marion County.

35. *Geolycosa missouriensis,* B.
L. Dunes Acres.

36. *Geolycosa wrightii,* Em.
E. Dunes Park; L. Ogden Dunes, Dunes Acres.

37. *Lycosa aspera,* Hentz (*Lycosa tigrina,* McCook).
E. Dunes Park; F. Lafayette; L. Dunes Acres, Ogden Dunes, Miller.

38. *Lycosa avara,* Keys. (*Trahosa avara,* Keys.)
B. North Vernon; F. Lafayette; L. Dunes Acres.

39. *Lycosa avida,* Walck. (*Lycosa communis,* Em.) (*Lycosa erratica*) (*Schizocosa avida,* Walck.).
B. Hammond; E. Richmond; Dunes Park; F. Lafayette; L. Dunes Acres, Miller, Ogden Dunes.

40. *Lycosa baltimoriana,* Keys.
L. Dunes Acres.

41. *Lycosa carolinensis,* Walck. *(Lycosa georgiana,* Walck.) *(Trachosa avara,* Keys.).
B. Wyandotte Cave, North Vernon, LaPorte County ; F. Lafayette.

42. *Lycosa frondicola,* Em. *(Lycosa nigrocentrus,* Em.) *(Lycosa modesta,* Thorell).
B. Mitchell, North Vernon, New Albany, Huntingburg ; E. Dunes Park ; F. Lafayette ; L. Ogden Dunes, Dunes Acres, Miller.

43. *Lycosa gulosa,* Walck. *(Lycosa kochii,* Em.) *(Alopecosa kochii,* Keys.).
B. Tippecanoe Lake, Huntingburg, Bass Lake, Medora, Grand Chain ; E. Richmond ; L. Smith.

44. *Lycosa helluo,* Walck. *(Lycosa nidicola,* Em.)
B. Tippecanoe Lake, Arlington, Bass Lake, Mitchell, Grand Chain, Medora, Mecca, Jeffersonville, Marion County, Huntingburg ; E. Dunes Park ; Em. Indiana ; F. Lafayette.

45. *Lycosa permunda,* Chamb.
L. Smith.

46. *Lycosa pratensis,* Em.
B. Vincennes, Wyandotte Cave, Bass Lake, Medora, Pine.

47. *Lycosa punctulata,* Hentz.
B. North Vernon, Greencastle.

48. *Lycosa rabida,* Walck. *(Lycosa scutulata,* Hentz)
B. Mitchell, Greencastle, Huntingburg ; E. Richmond, Dunes Park ; L. Ogden Dunes, Dunes Acres, Smith.

49. *Pirata febriculosus,* Becker.
E. Richmond.

50. *Pirata insularis,* Em.
B. Hammond ; E. Valparaiso ; L. Ogden Dunes, Smith.

51. *Pirata minutus,* Em.
E. Richmond ; F. Lafayette.

52. *Pirata marxi,* Stone. *(Pirata piratica,* Clerck).
B. Clear Lake, Knox County ; E. Richmond, Dunes Park ; L. Smith.

53. *Schizocosa bilineata,* Em.
E. Richmond, Valparaiso.

54. *Schizocosa crassipes,* Walck. *(Lycosa ocreata,* Hentz).
B. Tippecanoe Lake, Mitchell, Vawter Park, LaPorte County ; E. Valparaiso ; F. Lafayette ; L. Dunes Acres, Smith.

55. *Schizocosa saltatrix,* Hentz *(Lycosa gracilis,* B.).
B. Wyandotte Cave ; E. Dunes Park ; F. Lafayette ; L. Dunes Acres, Smith.

56. *Pardosa flavipalpis,* F. Camb. *(Pardosa flavipes,* Keys.).

57. *Pardosa lapidicina,* Em.
B. Bass Lake, Jeffersonville, Huntingburg.

58. *Pardosa milvina,* Hentz *(Pardosa nigropalpis,* Em.).
E. Richmond, Dunes Park ; F. Lafayette ; L. Ogden Dunes, Dunes Acres, Miller, Smith.

59. *Paradosa modica,* Blackwall *(Paradosa fuscula,* Thorell).
L. Dunes Acres.

60. *Pardosa moesta,* B.
L. Dunes Acres.

29. Oxyopidae

61. *Oxyopes salticus,* Hentz.
E. Richmond ; L. Dunes Acres.

32. Sicariidae

62. *Scytodes thoracia,* Latr.
E. Richmond.

33. Dictynidae

63. *Dictyna arundinaceoides,* Em.
F. Lafayette.

64. *Dictyna bicornis,* Em.
L. Ogden Dunes.

65. *Dictyna bostoniensis,* Em.
L. Dunes Acres, Ogden Dunes.

66. *Dictyna foliaca,* Hentz.
E. Richmond, Crooked Lake, Valparaiso, Dunes Park ; L. Dunes Acres, Ogden Dunes, Smith.

67. *Dictyna frondea,* Em.
B. Hammond, Arlington, Marshall County ; E. Dunes Park ; L. Dunes Acres, Ogden Dunes.

68. *Dictyna minuta,* Em.
E. Richmond, Crooked Lake, Valparaiso.

69. *Dictyna sublata,* Hentz.
B. Tippecanoe Lake, Grand Chain, Vawter Park ; E. Richmond, Crooked Lake, Valparaiso.

70. *Dictyna volucripes,* Keys.
L. Dunes Acres, Smith.

71. *Lathys foxii,* Marx. *(Dictynia foxii,* B.)
E. Richmond.

72. *Lathys pallida,* Em.
E. Richmond.

34. Theridiidae

73. *Asagena americana,* Em.
B. Wyandotte Cave ; E. Richmond ; F. Lafayette.

74. *Pedanostethus riparius,* Keys.
B. Knox County; E. Richmond.
75. *Pedanostethus primulus.* Em.
E. Richmond.
76. *Crustulina guttata,* Wider.
E. Richmond, Crooked Lake, Valparaiso; L. Ogden Dunes.
77. *Robertus riparius,* Keys.
L. Ogden Dunes.
78. *Sidusa borealis,* B.
E. Dunes Park; L. Dunes Acres.
79. *Steatoda borealis,* Hentz.
B. Greencastle; E. Richmond, Valparaiso; F. Lafayette; L. Ogden Dunes, Smith.
80. *Teutana triangulosus,* Hentz.
F. Lafayette.
81. *Latrodectus mactans,* Fabr.
B. Wyandotte Cave, Mitchell, North Vernon, Shoals, New Albany, Greencastle, Huntingburg; F. Lafayette.
82. *Argyrodes tigronum,* Hentz.
Ba. Mayfield's Cave.
83. *Euryopsis argentea,* Em.
E. Dunes Park; L. Ogden Dunes.
84. *Euryopsis funebris,* Hentz.
B. New Harmony; E. Richmond; F. Lafayette; L. Smith.
85. *Theridion cinereum,* Em.
L. Smith.
86. *Theridion differens,* Em.
B. Arlington, Bass Lake; E. Richmond, Crooked Lake, Valparaiso, Nashville, Dunes Park; L. Dunes Acres, Ogden Dunes.
87. *Theridion frondeum,* Hentz.
B. Vincennes, Grand Chain; E. Richmond, Crooked Lake, Valparaiso, Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.
88. *Theridion albomaculatum,* Camb.
L. Smith.
89. *Theridion kentuckyensis,* Keys.
B. Mayfield's Cave, Twin Cave; Ba. Mayfield's Cave, Truitt's Cave.
90. *Enoplognatha marmorata,* Hentz. *(Theridion marmoratum,* Hentz).
Hentz. Indianapolis.
91. *Theridion murarium,* Em.
B. Hammond, Arlington; E. Dunes Park; F. Lafayette; L. Dunes Acres, Ogden Dunes, Smith.
92. *Theridion pennsylvanicum,* Em.
E. Richmond, Crooked Lake.
93. *Theridion porteri,* B.
B. Porter's Cave, Truitt's Cave; Ba. Mayfield's Cave, Truitt's Cave; Bl. Porter's Cave, Truitt's Cave; McIndoo. Porter's Cave, Mayfield's Cave.
94. *Theridion rupicola,* Em.
L. Smith.
95. *Theridion spirale,* Em.
B. Pine, Lake County.
96. *Theridion tepidariorum,* C. Koch *(Theridion vulgare)*
B. Kosciusko County, Greencastle; E. Richmond, Valparaiso; Em. Wyandotte Cave; F. Lafayette; Hentz. Indianapolis; L. Smith.
97. *Theridula opulenta,* Walck.
E. Richmond.
98. *Nesticus carteri,* Em.
B. Bradford Cave, Porter Cave, Marengo Cave; Ba. Mayfield's Cave, Truitt's Cave; Bl. Porter Cave, Coon Cave, Marengo Caves; Em. Bradford Cave.
99. *Pholcus phalangioides,* Fuesslin.
E. Richmond, Crooked Lake.

36. Linyphiidae
100. *Bathyphantes canadensis,* Em.
E. Richmond.
101. *Bathyphantes formica,* Em.
L. Dunes Acres.
102. *Bathyphantes micara,* Em.
E. Richmond.
103. *Bathyphantes nigrinus,* Westring *(Linyphia nigrina,* Westring).
Ba. Mayfield's Cave; E. Richmond; F. Lafayette; L. Dunes Acres.
104. *Bathyphantes unimaculatus,* B.
E. Valparaiso.
105. *Bathyphantes zebra,* Em.
E. Richmond.
106. *Linyphia clathrata,* Sundervall.
E. Richmond; L. Ogden Dunes, Smith.
107. *Linyphia communis,* Hentz *(Frontinella communis* Hentz).
L. Smith.
108. *Linyphia conferta,* Hentz.
E. Richmond, Crooked Lake, Valparaiso.
109. *Linyphia lineata,* Linneaus *(Linyphia bucculenta,* Clerck) *(Bolyphantes lineata,* Keys.).
B. Greencastle; E. Richmond; F. Lafayette.
110. *Linyphia maculata,* Em.
L. Smith.
111. *Linyphia marginata,* C. Koch *(Linyphia marmoratus,* Hentz).
B. Arlington, Wyandotte Cave, Greencastle; Ba. Mayfield's

Cave; E. Richmond, Crooked Lake, Valparaiso; F. Lafayette; L. Smith.

112. *Linyphia phrygiana*, C. Koch.
B. Culver; E. Richmond, Crooked Lake, Nashville.

113. *Pityophantes phrygiana*, C. Koch.
L. Dunes Acres, Ogden Dunes, Smith.

114. *Linyphia pusilla*, Sundervall (*Linyphia mandibulata*, Em.).
E. Richmond; F. Lafayette; L. Dunes Acres.

115. *Linyphia weyeri*, Em.
Em. Wyandotte Cave; McIndoo, Marengo Cave; Packard, Wyandotte Cave.

116. *Microneta cornupalpis*, Camb.
E. Richmond.

117. *Trogolophantes cavernicolus*, Keys. (*Willibaldi cavernicola*, Keys.).
B. Donnelson's Cave; Ba. Mayfield's Cave, Donnelson's Cave, Twin Caves, Mitchell; Em. Wyandotte Cave; McIndoo, Shawnee Cave.

118. *Trogolophantes incertus*, Em. (*Linyphia incerta*, Em.).
Em. Wyandotte Cave.

119. *Ceraticulus emertoni*, Camb.
E. Richmond; L. Dunes Acres, Ogden Dunes, Smith.

120. *Ceraticulus fissiceps*, O. P. Camb.
E. Dunes Park; L. Dunes Acres, Ogden Dunes.

121. *Ceraticulus homologicus*, Crosby & Bishop.
L. Dunes Acres, Ogden Dunes.

122. *Ceraticulus minuta*, Em.
E. Richmond, Crooked Lake, Valparaiso; L. Ogden Dunes.

123. *Ceratiuella brunnea*, Em.
E. Richmond, Crooked Lake, Valparaiso.

124. *Anthobia mammouthia*, Tellkampf.
C. Wyandotte Cave; Em. Wyandotte Cave.

125. *Gongylidiellum pallidum*, Em.
E. Richmond, Crooked Lake.

126. *Oedothorax bidentatus*, Em. (*Gongylidiellum tridentatus*, Em.).
B. Porter Cave, Owen County.

127. *Oedothorax montiferus*, Em.
E. Richmond.

128. *Oedothorax platyrhinus*, Crosby.
E. Richmond.

129. *Ocdothorax probatus*, Camb.
E. Richmond, Crooked Lake, Valparaiso.

130. *Prosopetheca minuta*, Em.
E. Richmond.

131. *Tmeticus aestivalis*, Em.
E. Richmond, Crooked Lake, Valparaiso.

132. *Ceratinopsis anglicana*, Hentz.
E. Dunes Park; L. Dunes Acres.

133. *Ceratinopsis interpres*, Camb.
E. Richmond, Crooked Lake, Valparaiso, Nashville.

134. *Diplocephalus exiguus*, B.
E. Richmond.

135. *Erigone autumnalis*, Em.
L. Dunes Acres.

136. *Erigone dentigera*, Camb.
L. Dunes Acres.

137. *Erigone infernalis*, Keys.
Ba. Mayfield's Cave, Twin Cave; McIndoo, Mayfield's Cave.

138. *Erigone longipalpis*, Sundervall.
B. Arlington.

139. *Erigone tridentatus*, Em. (*Tmeticus tridentatus*, Em.).
Bl. Porter Cave.

140. *Grammonota inornata*, Em. (*Erigone inornata*, Em.).
E. Richmond; F. Lafayette.

141. *Hyposelistes flavens*, O. P. Camb.
L. Dunes Acres, Smith.

142. *Phanetta subterranea*, Keys. (*Linyphia subterranea*, Em.).
Ba. Wyandotte Cave, Truitt's Cave; Bl. Wyandotte Cave; Em. Wyandotte Cave, Bradford Cave; McIndoo. Spring Cave, Little Wyandotte, Salt Peter Cave.

143. *Trachelocamptus rostratus*, Em.
E. Richmond, Crooked Lake.

38. Uloboridae

144. *Uloborus americana*, Walck.
E. Richmond, Crooked Lake, Valparaiso; L. Ogden Dunes, Smith.

145. *Hyptiotes cavaticus*, Hentz.
E. Richmond, Crooked Lake; F. Lafayette; L. Ogden Dunes, Smith.

40. Argiopidae

146. *Argiope aurantia*, Lucas (*Argiope copinharia*, Walck).
B. Greencastle, Lake Maxinkuckee; E. Richmond, Valparaiso, Nashville, Dunes Park, Crooked Lake; F. Lafayette; L. Dunes Acres.

147. *Argiope trifasciata,* Forskal (*Argiope transversa,* Em.) (*Argyrapsis,* Walck).

B. Greencastle; E. Richmond, Valparaiso, Nashville, Dunes Park; F. Lafayette; L. Dunes Acres.

148. *Acacesia foliata,* Hentz.

B. Grand Chain, Greencastle; E. Richmond.

149. *Araneus angulatus,* Clerck (*Esperia angulata,* Clerck).

B. Greencastle; E. Richmond; L. Smith.

150. *Araneus arabesca,* Walck (*Epeira arabesca,* Walck) (*Neoscoma arabesca,* Walck) (*Aranea trinitatta,* Keys.) (*Epeira trinitatta,* Keys.).

B. Tippecanoe Lake, Hammond, Vincennes, Arlington, Wyandotte, Bass Lake, Culver, Wilder, Greencastle; E. Richmond, Crooked Lake, Valparaiso, Dunes Park; F. Lafayette; L. Dunes Acres, Ogden Dunes, Smith.

151. *Araneus arenatus,* Walck (*Epeira verrucosa,* Hentz) (*Mohadena verrucosa,* Camb.).

B. Vincennes, Wyandotte, Montezuma, Knox County, Greencastle; E. Richmond, Crooked Lake; F. Lafayette.

152. *Aranea benjaminus,* Walck (*Epeira benjamina,* Walck) (*Neoscona benjamina,* Walck) (*Epeira domicilorum,* Hentz).

153. *Araneus cavaticus,* Keys.

E. Richmond.

154. *Araneus cornutus,* Clerck (*Epeira cornuta,* Clerck) (*Epeira strix,* Hentz).

B. Tippecanoe Lake, Vincennes, Arlington, Grand Chain, Vawter Park, Culver, Knox County, Jeffersonville, Greencastle; E. Richmond; F. Lafayette.

155. *Araneus cucurbitinus,* Clerck (*Aranea displicata,* Hentz) (*Epeira displicata,* Hentz).

B. Tippecanoe Lake, Grand Chain, Attica, Shoals, Vawter Park.

156. *Araneus ectypus,* Walck (*Epeira infumata,* Hentz)

B. Grand Chain; E. Richmond.

157. *Aranea foliata,* Fourcroy.

L. Dunes Acres.

158. *Araneus hentzi,* B. (*Singa hentzi,* B.).

B. Cannelton.

159. *Araneus labyrintheus,* Hentz (*Epeira labyrinthea,* Hentz) (*Metaepeira labyrinthea,* Hentz).

B. Greencastle; L. Smith.

160. *Araneus marmoreus,* Clerck (*Epeira insularis,* Hentz).

B. Vincennes, Mitchell, Montezuma, Marion County, Greencastle; E. Richmond, Crooked Lake, Valparaiso, Nashville; F. Lafayette.

161. *Araneus miniatus,* Walck.

L. Smith.

162. *Araneus nigripes,* Keys. (*Singa nigripes,* Keys.).

B. Grand Chain.

163. *Araneus pegnia,* Walck (*Epeira globosa,* Keys.) (*Araneus globosa,* Keys.)

B. Greencastle; F. Lafayette.

164. *Araneus pratensis,* Hentz (*Neoscona pratense,* Hentz).

E. Dunes Park; L. Dunes Acres.

165. *Aranea raja,* Scopoli.

L. Ogden Dunes, Smith.

166. *Araneus sericatus,* Clerck (*Epeira sclopetaria,* Clerck) (*Epeira plectana,* Clerck).

B. Greencastle; F. Lafayette.

167. *Araneus stellatus,* Walck (*Plectana stellata,* Hentz) (*Epeira stellata,* Walck) (*Acanthoepeira stellata,* Walck).

B. Vincennes, Bass Lake, Grand Chain, North Vernon, Greencastle; E. Dunes Park; F. Lafayette; L. Dunes Acres.

168. *Araneus thaddeus,* Hentz (*Epeira thaddeus,* Hentz)

B. Greencastle; E. Dunes Park; L. Dunes Acres, Smith.

169. *Araneus trifolium,* Hentz (*Epeira trifolium,* Hentz).

B. Culver, Greencastle; E. Richmond, Crooked Lake, Valparaiso, Dunes Park; F. Lafayette; L. Dunes Acres, Smith.

170. *Araneus varians,* Em. (*Singa variabilis,* Em.).

B. Tippecanoe Lake.

171. *Cyclosa turbinata,* Walck (*Cyclosa caudata,* Hentz)

B. Greencastle; E. Dunes Park; F. Lafayette; L. Dunes Acres.

172. *Eustala anastera,* Walck (*Epeira eustala,* Walck) (*Epeira prompta,* Hentz).

B. Tippecanoe Lake, Hammond, Vincennes, Arlington, Wyandotte, Bass Lake, Grand Chain, Attica, Vawter Park, Pine, Culver, Knox County; E. Richmond, Valparaiso, Dunes Park; F. Lafayette; L. Dunes Acres, Ogden Dunes, Smith.

173. *Hentzii mitrata,* Hentz.
L. Dunes Acres, Ogden Dunes, Smith.

174. *Hentzii palmarum,* Hentz.
L. Dunes Acres, Ogden Dunes.

175. *Mangora gibberosa,* Hentz.
E. Richmond, Valparaiso, Nashville, Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.

176. *Mangora maculata,* Keys.
L. Dunes Acres, Ogden Dunes, Smith.

177. *Mangora placida,* Hentz.
B. Wyandotte, New Harmony.

178. *Glyptocranium bisaccatum,* Em. *(Ordgarius bisaccatum,* Em.).
E. Richmond.

179. *Glyptocranium cornigerum,* Hentz *(Ordgarius cornigerum,* Hentz).
B. Greencastle; F. Lafayette.

180. *Meta menardi,* Latr.
B. Mitchell, Greencastle; Ba. Strong's Cave, Twin Cave, Lower Twin Cave at Mitchell; Bl. Mayfield's, Strong's, Donnehue's, Donnelson's, Clifty, Wyandotte, Salt Peter Caves; Em. Bradford Cave, Wyandotte Cave; F. Lafayette; McIndoo. Shawnee Cave, Spring Cave, Salt Peter Cave.

181. *Nephila clavipes,* Linnaeus.
E. Richmond.

182. *Eucta vermiformis,* Em. *(Tetragnatha vermiformis,* Em.).
Kintner. Winona Lake.

183. *Leucauge venusta,* Walck *(Leucauge hortorum,* Hentz) *(Argyrepeira hortorum,* Hentz).
B. Arlington, Grand Chain, Greencastle; E. Richmond, Crooked Lake, Valparaiso, Dunes Park; F. Lafayette; L. Dunes Acres, Ogden Dunes, Smith.

184. *Pachygnatha tristriata,* C. Koch *(Pachygnatha brevis,* Koch).
B. New Harmony; E. Richmond; F. Lafayette.

185. *Pachygnatha xanthostoma,* C. Koch.
E. Richmond.

186. *Tetragnatha elongator,* Walck *(Tetragnatha grallator,* Hentz).
B. Tippecanoe Lake, Arlington, Kosciusko County, Huntingburg; E. Richmond, Crooked Lake, Valparaiso; F. Lafayette; Kintner. Winona Lake.

187. *Tetragnatha extensa,* Linnaeus.
B. Tippecanoe Lake, Vincennes, Grand Chain, Culver, Knox County.

188. *Tetragnatha laboriosa,* Hentz.
B. Tippecanoe Lake, Hammond, Arlington, Wyandotte, Mitchell, Greencastle, Grand Chain, Attica, Vawter Park, Pine, Lake County, Wilders; Ba. Donaldson's Cave, Twin Caves at Mitchell; E. Richmond, Crooked Lake, Nashville, Dunes Park; F. Lafayette; Kintner, Winona Lake; L. Dunes Acres, Ogden Dunes, Smith.

189. *Eugnatha pallescens,* F. Camb. *(Eugnatha pallidula,* B.) *(Tetragnatha pallidula,* Camb.).
Kintner. Winona Lake; L. Dunes Acres.

190. *Eugnatha straminea,* Em. *(Tetragnatha straminea,* Em.).
B. Tippecanoe Lake; E. Dunes Park; Kintner. Winona Lake; L. Dunes Acres, Smith.

191. *Theridiosoma gemmosum,* Koch *(Theridiosoma radiosum,* McCook).
Ba. Mayfield's Cave; L. Smith.

192. *Micrathena gracilis,* Walck *(Acrosoma gracilis,* Walck) *(Acrosoma rugosa,* Hentz) *(Epeira rugosa,* Hentz).
E. Richmond, Valparaiso; F. Lafayette; Hentz. Indianapolis.

193. *Microthena reduviana,* Walck *(Acrosoma mitrata,* Hentz).
B. Greencastle.

194. *Microthena sagittata,* Walck *(Epeira spinea,* Walck) *(Acrosoma sagittatum,* Walck) *(Acrosoma spinea,* Hentz).
B. Wyandotte, Mitchell, Greencastle; E. Richmond, Valparaiso, Dunes Park; F. Lafayette; Hentz. Indianapolis; L. Dunes Acres, Ogden Dunes, Smith.

41. Memetidae

195. *Ero furcatus,* Villers.
E. Richmond; F. Lafayette; L. Ogden Dunes.

196. *Mimetus interfector,* Hentz.
B. Shoals; E. Dunes Park.

44. Ctenidae
    197. *Anihita punctulata*, Hentz (*Ctenus punctulata*, Hentz).
    B. Wyandotte.
45. Drassidae
    198. *Callilepis imbecilla*, Keys.
    L. Dunes Acres, Ogden Dunes.
    199. *Gmophosa bicolor*, Hentz (*Gmaphosa sericata*, B.).
    E. Dunes Park; L. Ogden Dunes.
    200. *Drassodes neglectus*, Keys. (*Drassus neglectus*, Keys.).
    E. Dunes Park; L. Dunes Acres.
    201. *Drassodes robestus*, Em. (*Drassylus robustus*, B.).
    F. Lafayette.
    202. *Drassylus rufulus*, B.
    L. Smith.
    203. *Haplodrassus bicornus*, Em.
    L. Smith.
    204. *Haplodrassus signifer*, Em.
    L. Dunes, Miller, Smith.
    205. *Herpyllus vasifer*, Walck (*Herpyllus ecclesiasticus*, Hentz) (*Prosthesima ecclesiaticus*, Hentz).
    B. Greencastle; E. Richmond, Valparaiso; F. Lafayette; L. Dunes Acres, Ogden Dunes.
    206. *Nodocion sp.*
    E. Richmond.
    207. *Segiolus variegatus*, Hentz.
    B. Tippecanoe Lake; E. Richmond, Valparaiso.
    208. *Sosticus insularis*, B.
    E. Dunes Park; L. Dunes Acres.
    209. *Zelotes ater*, Hentz.
    B. Wyandotte; E. Richmond, Crooked Lake, Valparaiso.
    210. *Zelotes depressa*, Em. (*Prosthesima depressa*, Em.).
    F. Lafayette.
52. Thomisidae
    211. *Ebo latithorax*, Keys.
    E. Dunes Park; L. Dunes Acres.
    212. *Ebo pepimensis*, Gertsch.
    L. Ogden Dunes.
    213. *Philodromus alasciensis*, Keys.
    E. Dunes Park; L. Dunes Acres, Ogden Dunes.
    214. *Philodromus aureolus*, Clerck.
    B. Hammond, Vincennes, Knox County; L. Dunes Acres, Ogden Dunes.
    215. *Philodromus minutus*, B.
    E. Richmond.
    216. *Philodromus ornatus*, B.
    B. Arlington, Wilders; L. Smith.
    217. *Philodromus pernix*, Blackwall (*Philodromus vulgaris*, Hentz).
    B. Tippecanoe Lake, Bass Lake, Vincennes, Pine, Knox County, Greencastle; E. Richmond, Dunes Park; L. Dunes Acres, Ogden Dunes.
    218. *Philodromus placidus*, B.
    B. Vincennes, Arlington, Grand Chain, Pine, Culver.
    219. *Philodromus rufus*, Walck.
    B. Tippecanoe Lake, Arlington; L. Dunes Acres.
    220. *Philodromus thorelli*, Marx.
    L. Dunes Acres.
    221. *Tibellus martimus*, Menge.
    E. Dunes Park; L. Dunes Acres.
    222. *Tibellus oblongus*, Walck (*Tibellus duttoni*, Keys.).
    B. Pine, Lake County, Kosciusko County, Greencastle; E. Richmond, Valparaiso, Nashville; L. Dunes Acres, Smith.
    223. *Misumenoides aleatorius*, Hentz (*Runcinia aleatorius*, Hentz).
    B. Lake James, Hammond, Vincennes, Greencastle; E. Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.
    224. *Misumenops americana*, Keys. (*Misumena americana*, Keys.).
    B. Bass Lake, Grand Chain, Attica, Culver, Knox County, Greencastle; E. Valparaiso.
    225. *Misumenops asperatus*, Hentz (*Misumessus asperatus*, Hentz).
    B. Wyandotte, New Harmony, Pine, Huntingburg; E. Richmond, Valparaiso, Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.
    226. *Misumenops oblongus*, Keys. (*Misumessus oblongus*, Keys.).
    B. Veedersburg, Vawter Park, Greencastle; E. Richmond, Crooked Lake, Valparaiso; L. Dunes Acres, Ogden Dunes, Smith.
    227. *Oxyptila americana*, B.
    L. Smith.
    228. *Oxyptila conspurcata*, Thorell.
    B. Cypress Swamp, Pine, Knox County.
    229. *Oxyptila monroensis*, Keys.
    E. Richmond.
    230. *Synaena parvulum*, Keys.
    B. Arlington, Grand Chain, Veedersburg, Culver.
    231. *Tmarus angulatus*, Walck.
    E. Richmond, Crooked Lake, Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.

232. *Xysticus banksi*, Bryant.
L. Smith.

233. *Xysticus elegans*, Keys.
L. Smith.

234. *Xysticus ferox*, Hentz (*Xysticus stomachosus*, Keys.).
B. Vincennes, Arlington, Wyandotte, Bass Lake, Culver, Greencastle; E. Richmond, Valparaiso; L. Smith.

235. *Xysticus fraternis*, B.
E. Richmond, Crooked Lake, Valparaiso; L. Dunes Acres, Ogden Dunes, Smith.

236. *Xysticus gulosa*, Keys.
B. Wilder, Greencastle; E. Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.

237. *Xysticus luctans*, C. Koch (*Xysticus quadrilineatus*, C. Koch).
B. Kosciusko County.

238. *Xysticus nervosus*, B.
B. Tippecanoe, Culver, Greencastle; E. Richmond, Valparaiso.

239. *Xysticus transversus*, B.
B. New Harmony.

240. *Xysticus triguttatus*, Keys.
B. Hammond, Wilder; E. Richmond, Valparaiso, Dunes Park; L. Dunes Acres, Ogden Dunes.

241. *Xysticus versicolor*, Keys. (*Coriarachne versicolor*, Keys.).
B. Wyandotte, Vincennes, Mecca, New Albany, Greencastle; L. Dunes Acres, Ogden Dunes, Smith.

54. Clubionidae

242. *Chiracanthium inclusium*, Hentz.
B. Vincennes.

243. *Clubiona abbotii*, L. Koch (*Clubiona rubra*, Keys.).
B. Arlington, Marshall County; F. Lafayette.

244. *Clubiona obesa*, Hentz.
E. Richmond, Valparaiso; L. Ogden Dunes, Smith.

245. *Clubiona pallens*, Hentz.
E. Richmond, Valparaiso; L. Dunes Acres, Smith.

246. *Clubiona tribola*, B.
B. Wyandotte.

247. *Anyphaena celer*, Hentz (*Clubiona celer*, Hentz) (*Anyphaena incerta).*
E. Dunes Park; L. Ogden Dunes, Smith.

248. *Anyphaena gracilis*, Hentz (*Microthena gracilis*, Walck) (*Acrosona gracilis*, Walck) (*Epeira rugosa).*
B. Hammond, Veedersburg.

249. *Anyphaena pectorosa*, L. Koch.
E. Richmond; L. Smith.

250. *Anyphaena rubra*, Em.
F. Lafayette.

251. *Anyphaena saltabunda*, Hentz.
E. Richmond, Valparaiso, Nashville.

252. *Aysha gracilis*, Hentz.
L. Dunes Acres, Ogden Dunes, Smith.

253. *Agroeca minuta*, B.
E. Richmond, Crooked Lake; L. Ogden Dunes.

254. *Agroeca pratensis*, Em.
B. Arlington, Marshall County.

255. *Phrurolithus alarius*, Hentz (*Phrurolithus palustris*, B.).
B. Grand Chain, Posey County; E. Richmond, Crooked Lake; L. Ogden Dunes.

256. *Phrurolithus similis*, B.
E. Richmond.

257. *Trachelas tranquillus*, Hentz (*Trachelas ruber*, Hentz).
B. Tippecanoe Lake, Greencastle, Huntingburg; E. Richmond, Valparaiso, Dunes Park; F. Lafayette; L. Dunes Acres.

258. *Castaneira cingulata*, C. Koch.
E. Richmond, Crooked Lake, Valparaiso, Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.

259. *Castaneira descripta*, Hentz (*Tharagla crocata*, B.).
B. Greencastle; F. Lafayette.

260. *Castaneira longipalpis*, Hentz.
B. Tippecanoe Lake, Knox County; E. Richmond; L. Smith.

261. *Castaneira trilineata*, C. Koch (*Thargalia trilineata*, B.)
F. Lafayette; Hentz. Indiana; L. Dunes Acres.

262. *Micraria aurata*, Hentz (*Micraria longipes*, Hentz).
E. Dunes Park; L. Dunes Acres.

55. Attidae

263. *Syncmosyna formica*, Hentz.
B. Arlington, Culver; E. Richmond.

264. *Thiodina sylvana*, Hentz (*Thiodina retarius*, Hentz).
B. Wyandotte, Grand Chain, Huntingburg.

265. *Maevia vittata*, Hentz.
B. Arlington, New Albany; E. Richmond, Crooked Lake, Valparaiso, Nashville, Dunes Park; L. Dunes Acres, Ogden Dunes, Smith.

266. *Zygoballus bettini,* Packham.
B. Knox County; E. Dunes Park; L. Dunes Acres, Ogden Dunes.

267. *Zygoballus nervosus,* Peckham.
E. Dunes Park.

268. *Evarcha hoyi,* Peckham.
L. Dunes Acres.

269. *Habrocestum pulex,* Hentz.
B. Wyandotte; E. Richmond, Valparaiso; F. Lafayette; L. Ogden Dunes, Smith.

270. *Pellenes agilis,* B.
E. Dunes Park; L. Dunes Acres, Ogden Dunes.

271. *Pellenes arizonenses,* B. *(Saites pulex,* Hentz).
L. Ogden Dunes.

272. *Pellenes borealis,* B.
E. Crooked Lake, Dunes Park; L. Dunes Acres, Ogden Dunes.

273. *Pellenes calcaratus,* B.
E. Dunes Park; L. Dunes Acres, Ogden Dunes.

274. *Pellenes roseus,* Hentz.
E. Crooked Lake, Valparaiso.

275. *Phlegra fasciata,* Hohn *(Phlegra leopardus,* Hohn).
B. New Harmony.

276. *Tutelina elegans,* Hentz *(Dendryphantes elegans,* Hentz).
B. Hammond, Arlington, Bass Lake, Shoals, Culver, Knox County; F. Lafayette; L. Dunes Acres, Smith.

277. *Admestina tibialis,* C. L. Koch.
E. Dunes Park; L. Ogden Dunes, Smith.

278. *Agassa cyanea,* Hentz *(Homolattus cyanea,* Hentz).
B. Hammond.

279. *Dendryphantes (Phidippus) audax,* Hentz *(Phidippus morsitans,* Peckham) *(Phidippus audax,* Peckham) *(Attus tripunctatus,* Hentz).
B. Arlington, Bass Lake, New Harmony, Grand Chain, Attica, N. Vernon, Culver, Greencastle, Huntingburg; E. Richmond, Crooked Lake, Valparaiso. Dunes Park; F. Lafayette; Hentz. Indianapolis; L. Dunes Acres, Ogden Dunes, Smith.

280. *Dendryphantes (Paraphidippus) aurantius,* Lucas *(Phidippus multicolor,* Peckham).
B. Vincennes, Wyandotte, Grand Chain, Shoals, Greencastle.

281. *Dendryphantes (Metaphidippus) capitatus,* Hentz *(Dendryphantes octavius,* Hentz).
B. Hammond, Arlington, Wyandotte, Bass Lake, Grand Chain, Attica, Shoals, Veedersburg, Vawter Park, Pine, New Albany, Culver; E. Richmond, Crooked Lake, Valparaiso, Nashville; F. Lafayette.

282. *Dendryphantes (Phidippus) clarus,* Keys.
E. Richmond, Nashville; L. Dunes Acres, Ogden Dunes, Smith.

283. *Dendryphantes (Phidippus) cardinalis,* Hentz.
B. Mount Vernon.

284. *Dendryphantes (Phidippus) deceptus. (Phidippus brunnea,* E. Cambridge).
L. Dunes Acres, Smith.

285. *Dendryphantes (metaphidippus) flavous,* Peckham.
L. Dunes Acres.

286. *Dendryphantes (Phidippus) formosus, Peckham. (Philaeus rimator,* Peckham).
B. Greencastle.

287. *Dendryphantes (Phidippus) insignarius,* C. Koch.
B. Hammond, Arlington; L. Dunes Acres, Ogden Dunes, Smith.

288. *Dendryphantes (Paraphidippus) marginatus,* Walck *(Dendryphantes militaris,* Em.).
B. Wyandotte, Mitchell; L. Dunes Acres, Ogden Acres, Smith.

289. *Dendryphantes (Phidippus) McCooki.*
L. Dunes Acres.

290. *Dendryphantes (metaphidippus) protervus,* Walck.
L. Smith.

291. *Dendryphantes (Phidippus) purpuratus,* Keys.
L. Ogden Dunes.

292. *Dendryphantes (Phidippus) putnami,* Peckham. *(Phidippus putnami,* Peckham).
B. Knox County, Grand Chain.

293. *Dendryphantes rarus,* Hentz.
B. Greencastle.

294. *Dendryphantes (Phidippus) whitmanni, Peckham. (Dendryphantes rufus,* Hentz) *(Phidippus rufus,* Peckham).

B. Vincennes, Wyandotte, Bass Lake, Grand Chain, Wilder, Huntingburg; F. Lafayette.

295. *Icius hartii,* Em.
E. Richmond, Nashville.

296. *Talavera minuta,* B.
L. Ogden Dunes.

297. *Neon nelli,* Peckham.
E. Richmond, Crooked Lake, Valparaiso, Nashville.

298. *Hyctia pikei,* Peckham.
E. Richmond.

299. *Sitticus palustris,* Peckham.
E. Dunes Park; L. Dunes Acres, Ogden Dunes.

300. *Marpissa undata,* DeGeer *(Marpissa famaliaris,* Hentz).
B. Greencastle, Huntingburg; L. Smith.

301. *Wala mitrata,* Hentz *(Icius mitrata,* Hentz).
B. Arlington, Grand Chain, Shoals, Veedersburg, Vawter Park.

302. *Wala palmarum,* Hentz.
B. Hammond, Arlington, Pine.

303. *Salticus scenicus,* Clerck *(Epiblem scenicus,* Clerck).
E. Richmond.

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Histological Effects of Itrumil, Thiouracil and Thiourea on the Endostyle of *Lampetra lamottenii*

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Ammocoete larvae of *Lampetra lamottenii* (25-147 mm. long) were immersed in individual concentrations of 0.033% thiourea, 0.1% thiouracil, and 0.1% itrumil for 12 days at 70°C. The animals then were fixed in Zenker's fluid, stained with Heidenhain's iron haematoxylin and sections 10 microns thick were prepared.

Observation revealed that the dorsal gland cylinders were primarily affected. These structures were decreased in size and the syncytial type I cells, which comprise them, were histolyzed and most of the contained nuclei were fragmented. Similar but less severe effects were noted in the ventral gland cylinders. Histolysis was more pronounced in itrumil- and thiourea-treated specimens. The type III cells exhibited early signs of histolysis and the total size of the endostylar chambers showed a decrease in the treated animals. Similar effects were observed in all the experimental ammocoetes regardless of size. Controls were carefully maintained and observed. Jones (1947, Nature, London. 160:636-639) who did similar work on ammocoetes failed to report histolysis of cells after treatment with thiourea but did observe that nuclei of the endostylar gland became basally placed.

Since the antithyroid compounds have elicited a response in the endostyle of ammocoetes; experiments are being conducted to ascertain whether or not the endostyle has a secretory cycle similar to that of the thyroid gland in higher vertebrates. This is being tested by surgical ablation of the pituitary gland and thyroxin addition when the goitrogenic compounds are simultaneously administered.

In Vitro Survival Time of Swine Lungworms

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Lungworms from the posterior lobes of lungs of swine slaughtered at Major Bros. Packing Co., Mishawaka, Ind., were identified as *Metastrongylus apri (= elongatus)* and *Choerostrongylus pudendotectus*. Random samples from hosts on different days of slaughtering showed that the former species was the more prevalent. Experiments were performed to determine the maximum survival time of these worms in non-nutrient media at room temperature (21°-25°C), 4°C, and 38°C, the latter being approximately the body temperature of the pig. At least 10 worms (no differentiation of sex or species) were placed in 100 cc. of more than 50 different solutions. Some of the various solutions tried were: physiological saline; Ringers; Ringers plus varying amounts of sodium, potassium, and calcium chloride; Tyrode's; Ringer-Locke; Krebs-Ringer; Kronecker's; distilled water; doubly distilled water; and tap water.

Although there was no sure way of determining whether the worms were alive or dead, the author resorted to the procedure used by other workers in this field. This consisted of probing the worms with a blunt instrument (camel's hair brush in this case) and if they showed undulatory movements they were alive. This method obviously does not give any indication of the physiological state of the organism. It was observed just before actual death the worms remained outstretched and moved only slightly when probed. This condition usually preceded death by a few hours.

Maximum survival in modified Bueding's Basic Filarial medium (pH 7.0, sodium chloride, potassium chloride, magnesium chloride, calcium chloride, and sodium phosphate) was 14 days at room temperature. Survival in this solution at 38°C was limited to approximately 5 days and activity was greater at this than at room temperature. This activity may cause a more rapid depletion of glycogen and ultimately hasten death. In Bueding's solution at 4°C, the worms survived approximately one day.

Minimal survival time at room temperature was less than one hour in distilled water, tap water, doubly distilled water, and certain non-isotonic solutions. The worms literally explode soon after they are immersed in these solutions.

Since these worms live in the bronchioles of the lungs where oxygen is abundant, it was thought that aeration of the media might increase the survival time. Continuous aeration of the media, however, had no effect. Many workers state sterile media favors *in vitro* survival, but such was not the case in the present study.

Developmental Rate of the Sheep Stomach Worm, *Haemonchus contortus*

JOHN D. MIZELLE and JOSEPH A. BERBERIAN, University of Notre Dame

Eggs in the morula stage were secured from adult parasites acquired from Armour and Co., Chicago, Illinois. Individual batches of these were placed in tap water and a feces-decoction filtrate and incubated at several temperatures between the established minimum and maximum until attainment of the third-stage or infective larvae. Velocity curves of development were made according to the method of Shelford (1927, Ill. Nat. Hist. Survey Bull. 16:311-440).

The number of developmental units required to complete development from the morula to the third-stage or infective larva are 1019 and 1081, respectively, in covered containers of tap water and feces-decoction filtrate. These developmental units are 706 and 1074, respectively, for development in uncovered containers of tap water and feces-decoction filtrate.

At optimum temperature (33.3°C), *H. contortus* ova and larvae complete development to the third-stage larvae in uncovered containers in 60 hours in tap water or feces-decoction filtrate and in 65 hours in covered containers of each of these media.

Minimum lethal temperature for ova of *H. contortus* is 5.56°C, Approximately 5% of the ova hatch at 8.89° C with prolonged incubation. The minimum temperature at which third-stage larvae were produced was 14.4°C in feces-decoction filtrate, but only 1% reached this stage in 251 hours in covered and uncovered containers. The minimum temperature for 100% development to the third-stage larva was 17.8°C in feces-decoction filtrate and 21.1° C in tap water in 201.5 hours and 156 hours, respectively.

The maximum temperature which permitted development to the third-stage larva was 36.7°C, but only 10% of the ova developed to this stage. This development occurred in covered dishes of tap water and required 132 hours. At 35.6°C all "cultures" developed 100% infective larvae in 70-80 hours.

A temperature of 37.8°C proved lethal in 5 days.

Exposure of ova at 4°C proved lethal in 82 hours. Removals from 4°C to optimum temperature (33.3°C) after exposures of 11, 34 and 59 hours showed a progressive retardation of development of infective larvae.

Ova incubated at 33.3°C and removed to 4°C at periods of 11 and 34 hours showed no further development. Ova exposed for 59 hours before removal to this temperature developed to third-stage larvae, proving that once a critical stage (advanced second-stage larva) in development is reached, development and survival of infective larvae are not inhibited by a temperature of 4°C.

Histochemical Demonstration of Vitamin C in *Hymenolepis nana* var. *fraterna*

ROBERT M. COLEMAN,[1] University of Notre Dame

The presence of ascorbic acid in *Hymenolepis nana* var. *fraterna* has been demonstrated by a series of cytological techniques based on the classical acetic-silver nitrate technique of Giroud and Leblond, 1934 (Comptes Rendus de la Societe de Biologie, 115:705). This consists essentially of successive treatment of the organisms in acetic-silver nitrate, sodium sulphite, sodium thiosulphate, and distilled water in the dark at room temperature. A dark green filter was employed to facilitate handling of the worms under these conditions. The presence of the reduced form of ascorbic acid is indicated by precipitates of reduced silver deposited in the tissues. Sodium thiosulphate was necessary to remove the silver chloride, which may be formed by the action of silver nitrate upon cellular chlorides. The inhibition of a black precipitate of silver sulphide, produced by the action of sodium thiosulphate upon silver nitrate, takes place by the addition of sodium sulphite prior to the thiosulphate. Immersion time intervals, as well as concentrations of the above compounds, were varied. A freezing technique, as outlined by Glick, 1949 (*in* Techniques of Histo- and Cytochemistry, Interscience Publishers, N. Y.) was also employed. The validity of the acetic-silver nitrate technique has been reviewed by many authors, outstanding perhaps, are the reviews of Bourne, 1936 (Anatomical Record 66:369), and Sosa, 1952 (Experimental Cell Research 31(1):184). Some of the infected mice were on a normal diet, while others were on an ascorbic acid supplemented diet prior to the determinations.

Whole mounts and serial sections of Hymenolepis showed the presence of dark bodies, suggesting the presence of reduced ascorbic acid. Particles in the younger proglottids appeared as dense reticuli, and as fine black granules distributed irregularly in the cytoplasm. Granules were also observed in the oncospheres. The appearance of the reticuli suggested the configuration of the Golgi apparatus.

Bourne, 1951 (Cytology and Cell Physiology, Oxford at the Clarendon Press, London) and others have demonstrated that a topographical coincidence exists between the Golgi apparatus, and vitamin C. Bourne, in some cases, demonstrated the presence of ascorbic acid in the internal region of the mitochondria. Sosa, (loc. sit.) contests this, and claims that the accumulation of the granules in a juxtanuclear zone, may not necessarily mean their localization inside the Golgi apparatus, or even inside the Golgi zone. He disagrees also with Hirsch's theory of the active part taken by the Golgi apparatus in ascorbic acid storage in the cell, and points out that there is no method for simultaneously and completely revealing the Golgi apparatus and the vitamin C granules.

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The presence of vitamin C in this organism is of interest since mice are known not to require ascorbic acid in their diet, under normal conditions. Four possibilities are suggested as to the vitamin source in this organism. The parasite may be getting this substance from 1) the host's diet as is the case for riboflavin (Addis and Chandler, 1944; Journal of Parasitology 30:369); 2) bacteria in the intestine since bacteria do not appear to require vitamin C; 3) the mucosa of the host as is the case with vitamins A, B_1, D, and E (Addis and Chandler (loc. cit.); or 4) the parasite may be synthesizing vitamin C, which may be possible since ascorbic acid synthesis is dependent on the products of glucose metabolism (Roy and Guha 1946, Nature 158:238).

Since vitamin C possesses strong reducing powers, and is capable, with glutathione, of forming an oxidation-reduction system, its possible value as a respiratory mechanism in this tapeworm is readily recognized.

A micro-chemical determination for ascorbic acid, employing the photometric indophenol-xylene procedure, will be undertaken to substantiate the above results, and determine the percentage of vitamin present.

Effect of Cyanide on the Oxygen Consumption of Developing Ova of *Ascaris lumbricoides* var. *suum*

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This research was undertaken as a result of incomplete information revealed by the literature regarding the cyanide-sensitivity of developing pig-ascarid ova.

Using the Warburg constant volume respirometer and the technique for use of cyanide given by Robbie (1945, J. Indust. Hyg. Toxicol. 27:136-145), some indications of the materials used in embryonic respiration were suggested.

Four concentrations of cyanide varying from 0.78 x 10^{-3} to 5.6 x 10^{-3}M HCN were utilized in the experiments on the uncleaved eggs and for those in the 2-4 celled stage. As yet, these are the only stages in the embryogeny of this organism that have been investigated.

A typical experimental run involved.

1) 5 experimental manometer flasks containing a given cyanide concentration, *Ascaris* saline solution, and a given number of *Ascaris* eggs.
2) 4 control flasks containing *Ascaris* saline, *Ascaris* ova and 5% KOH in the center well. (no cyanide)
3) a flask containing distilled water for correction of barometric pressure and temperature variations in the water bath.
4) a flask (blank) containing the cyanide mixture in the center well and *Ascaris* saline in the experimental compartment. (no eggs)

The blank was used for determination of the cyanide concentration utilized, this being carried out by means of the Fisher photoelectric colorimeter.

Four concentrations of HCN varying from 0.78 x 10^{-3} to 5.0 x 10^{-3}M show a progressively powerful action in depressing respiration in the uncleaved egg. The inhibition produced by this range of HCN concentrations varied from 43 to 67% of the control value. Since the presence of cytochrome oxidase has been demonstrated in adult *Ascaris lumbricoides* var. *suum* by Laser in 1944 (Biochem. J. 38:333-338), it seems reasonable to conclude that by increasing the concentration of cyanide in the medium, a greater part of the cyanide-sensitive system was affected and that the extent of saturation of cytochrome oxidase in the cell varies directly as the cyanide concentration.

Similarly, individual experiments on pig-ascarid ova in the 2-4 celled stage were conducted at 4 concentrations of HCN. There exists a slightly different condition in early cleavage than in the uncleaved egg. It was observed that HCN produced maximum effect much earlier than in the case of the uncleaved egg. Respiration depression varied directly as the concentration of HCN in both batches of eggs but whereas a maximum effect was being approached at a concentration of 5.0 x 10^{-3}M HCN in the case of the uncleaved eggs, the maximum effect on the 2-4 celled stage was reached at a concentration of 2.8 x 10^{-3}M HCN. Therefore a more rapid response to the action of cyanide was apparent in the 2-4 celled embryo, a maximal inhibition of 87% being evident in 2.8 x 10^{-3}M HCN.

Since the cyanide-sensitive portion of the system may be recognized by subjection to cyanide which combines with cytochrome oxidase and also since this portion of the system is identifiable with carbohydrate oxidation, certain conclusions are suggested regarding the type of food material utilized in embryonic respiration.

The uncleaved egg shows less cyanide depression effects than in the case of the 2-4 celled embryo. This suggests that initial oxidation involves more fat metabolism than in the 2-4 celled stage. This is supported by the fact that the respiratory quotient (R.Q.) during initial development in the case of the present experimental organism is 0.81 which is indicative of some fat utilization. Likewise, in the 2-4 celled stage (third day of incubation) a beginning of carbohydrate metabolism may occur as shown by a lesser cyanide-insensitive portion of respiration together with an R.Q. of 0.90.

The Effects of —10°C. and —16°C. on the Viability and Infectivity of Trichinella Spiralis Larvae

ROBERT J. SHAVER, University of Notre Dame

The utilization of low temperatures to destroy encysted larvae of *Trichinella spiralis* has been practiced for many years. It was felt that the work of previous workers (Augustine, D. L., 1933; Blair, J. B., and O. W. Lang, 1934; Gould, S. E., 1945; Nolf, L. O., and J. M. Edney, 1935; Ransom, B. H., 1916) lacked precision in that after treatment, viability of the experimental organisms was not checked by testing the infectivity of the larvae, or if checked, the work was not done in a comprehensive manner.

The primary purpose of the present experiments was to test the resistance of *T. spiralis* larvae (encysted in rat muscle) to low temperature effects and to determine whether they are, if viable, capable of producing an infection, by means of comprehensive feeding experiments involving young, susceptible, laboratory-reared albino rats.

Experiment 1 was designed to verify the period required for larvae of *T. spiralis* to develop to sexual maturity and produce infective larvae in the diaphragm of albino rats. Each of twelve, fifty-day-old rats were fed 1100 larvae. Two of these were killed on each of the following days after infection: 14, 16, 17, 18, 21, 28. The diaphragms were removed, digested, and observations made for the presence of larvae (Table I).

Experiment 2 was planned in an attempt to demonstrate the resistance of different age larvae to —16°C. Eighteen fifty-day-old rats were fed 1100 larvae each. Two of these were autopsied on each of the following days after infection: 18, 21, 28, 35, 42, 49, 63, 94, 100. The diaphragms of each of these was exposed to —16°C. for three minutes. One hundred-fifty of the larvae recovered from each diaphragm were fed to individual rats (50-70 days old). These test rats were sacrificed 30 days after infection and the larvae digested and counted (Table II).

Experiment 3 was conducted to determine the margin of safety provided by an exposure of —16°C. for three minutes as used in experiment 2. Four rats were heavily infected with *T. spiralis* and autopsied when the infections were one hundred days old.* The diaphragms of two of these were exposed to —16°C. for three minutes and those from the other two rats were exposed to the same temperature for one minute. Then three hundred of the larvae digested from each diaphragm were fed to individual fifty-day-old rats. Thirty days after infection these animals were sacrificed and the diaphragms were examined for the presence of encysted larvae (Table III).

Experiment 4 was designed to demonstrate the resistance of well established (70-day) infections of larvae of *T. spiralis* to —10°C. Sixteen fifty-day old rats were heavily infected with *T. spiralis* and sacrificed when the infections were seventy days old. These experimental animals

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* The age of infections cited herein was reckoned from the time of ingestion of infective larvae.

TABLE I. Period required for larvae of *T. spiralis* to develop to sexual maturity and produce ineffective larvae in the diaphragm of albino rats.

Rat No.	Days After Ingestion of Infective Larvae	Larvae Present in Diaphragm
1	14	0
2		0
3	16	0
4		0
5	17	0
6		0
7	18	7
8		10
9	21	26
10		34
11	28	720
12		112

were divided into groups of four each. The diaphragms of one group were subjected to —10°C. for one minute, those of the second group were exposed to this temperature for three minutes, the diaphragms of the third group were exposed to —10°C. for five minutes; the fourth group for ten minutes. Two hundred-forty of the larvae recovered from each diaphragm were then fed to each of sixteen fifty-day old rats. Eight fifty-day old rats were fed two hundred-forty untreated larvae as controls. These were autopsied when the infections were thirty days old and the recovered larvae were counted (Table IV).

Results and Discussion

The twelve albino rats, each of which was infected with 1100 larvae of *T. spiralis* in experiment 1, first showed the presence of larvae in the diaphragm on the eighteenth day after infection. This agrees very closely with the findings of Nolf and Edney (1935) who established infections after feeding trichinous muscle from rats which had been infected seventeen days previously.

Apparently, the larvae of *T. spiralis* begin to attain infectivity by the time they enter the diaphragm in experimental infections. This is

TABLE II. Resistance of different-age larvae after exposure to —16°C. for three minutes as tested by feeding 150 of treated larvae to 50-70 day old rats and recovering second generation larvae from the diaphragms in 30 days.

Rat No.	Age of Larvae in Days After Infection	Test Rat No.		No. of Larvae Recovered	
		Expt.	Control	Expt.	Control
1	18	19	37	0	7
2		20	38	0	10
3	21	21	39	0	26
4		22	40	0	34
5	28	23	41	0	720
6		24	42	0	112
7	35	25	43	0	101
8		26	44	0	284
9	42	27	45	0	246
10		28	46	0	68
11	49	29	47	0	204
12		30	48	0	138
13	63	31	49	0	78
14		32	50	0	66
15	94	33	51	0	93
16		34	52	0	116
17	100	35	53	0	82
18		36	54	0	109

supported by the fact that one hundred-fifty larvae obtained from this muscle of rats which had been infected eighteen days previously, produced light infections when fed to test animals. There is a progressive increase in infectivity from the eighteenth to the twenty-eighth day after infection as shown on Table I.

A three-minute exposure at —16°C. was selected as the first in a series of experiments to demonstrate the resistance of *T. spiralis* larvae of different ages to low temperature effect. This was considered a reliable starting point on the basis of experiments by previous investigators.

It is significant that one hundred per cent of the larvae in experiment 2, from infections ranging in age from eighteen to one hundred days, were killed at —16°C. during an exposure of three minutes (Table II). The discrepancy between low-temperature requirements for production of one hundred per cent lethality in the rat host as demonstrated by the work of Blair and Lang (1934) and the present investigator, is maximum. There are several possible explanations which may be applicable here. Firstly, Blair and Lang interpreted viability by observation of motility which is proven fallacious by the present study. In each case in experiment 2, the larvae were motile when fed to the test animals but, as shown in Table 2, none produced an infection. Secondly, fast freezing may not be as detrimental as fast thawing which was accomplished in the present study through the use of physiological saline at room temperature. Blair and Lang thawed their material in the air at room temperature. Thirdly, the drop in temperature may have been faster in the present study than in the work of Blair and Lang.

After obtaining one hundred per cent lethality at —16°C. during a three-minute exposure, the author decided to determine the margin of safety provided by this procedure. Therefore, trichinous diaphragms harboring one-hundred day old infections were exposed to —16°C. for one- and three-minute periods. The production of infections by trichinous diaphragms exposed for one minute demonstrated the margin of safety to be narrow (Table IV).

TABLE III. Effects of exposure to —16°C. (for 1 and 3 minutes) on 100-day old *T. spiralis* larvae as evidenced by feeding 300 of the experimental larvae to individual 50-day old test rats, and presence of larvae in diaphragms after 30 days.

Rat No.	Exposure Time in Minutes	Test Rats No.	Recovered Larvae from Diaphragms
1	3	5	0
2		6	0
3	1	7	17
4		8	21

TABLE IV. Resistance of larvae from 70-day old infections of *T. spiralis* after exposure to —10°C. for varying periods of time, as revealed by larvae recovered from the diaphragms of 50-day old test rats 30 days after each was infected with 240 treated larvae.

Exposure in Minutes	Rats		Larvae Recovered	
	Expt.	Control	Expt.	Control
10	1	17	0	121
	2		0	
	3	18	0	109
	4		0	
5	5	19	0	121
	6		24	
	7	20	14	109
	8		5	
3	9	21	15	76
	10		9	
	11	22	81	56
	12		33	
1	13	23	54	69
	14		68	
	15	24	83	71
	16		175	

Having discovered marked lethal effects to larvae of *T. spiralis* during an exposure of —16°C. for three minutes, experiment 4 was performed to test the resistance of well-established (70-day) infections of these larvae to —10°C. Table IV shows that viability at this temperature as revealed by feeding experiments varied, inversely as the period of exposure. Ten minutes at this temperature produced one hundred per cent lethality.

Summary

1. Infective larvae of *Trichinella spiralis* first appear in the diaphragm of the rat host on the eighteenth day after ingestion of trichinous material.

2. *T. spiralis* larvae begin to attain infectivity by the time they are present in the diaphragm in experimental infections. Infectivity increases progressively from the eighteenth to the twenty-eighth day after infection.

3. A rapidly attained temperature of —16°C. for three minutes in conjunction with quick thawing is one hundred per cent lethal to infections of *T. spiralis* larvae ranging in age from eighteen to one hundred days. The margin of safety of an exposure to —16°C. for three minutes is narrow since one-minute exposures at the same temperature are not one hundred per cent lethal to trichina larvae.

4. Feeding experiments suggest that motility is fallacious as a criterion of infectivity.

5. Viability of *T. spiralis* larvae exposed to —10°C. for one, three, five, and ten minutes varies inversely as the period of exposure. A ten-minute exposure at this temperature kills *Trichinella spiralis* larvae.

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Every year a few more papers are submitted than can be published with the available funds. Therefore, not all papers received can be included in the Proceedings. Of those accepted, it is usually necessary that some be reduced in length by the authors, before publication. Manuscripts prepared concisely, in the style recommended above, will receive first consideration. Authors should not expect to publish very long papers in the Proceedings. Among papers of primarily regional interest, e.g., in certain aspects of botany, zoology, geography, and anthropology, those dealing with Indiana material will be accorded preference.

The selection of papers for the Proceedings is the responsibility of the Editorial Committee.

INDEX

INDEX TO VOLUME 62

Acetic acid, metabolism in tomato, 101
Acorns in the Indian diet, 56
Actinophage, 64
Adjustment, 293
Agabus confusus, 171
Alfalfa, insects affecting seed production, 181
Algae, growth of, 99
  of Lake Wawasee, 98
Alkylation reaction, 158
Allen, M., 144
Alternate routes of metabolism, 64
American Pharmaceutical Association, 278
Ammocoetes, 318
Amylase, bacterial, 65
Andrew, K. L., 291
Anthropology division, 52
Antibiotics, effect on bacterial reduction of triphenyltetrazolium chloride, 63
Aquatic plants, respiration of Verduin method, 104
Araneology of Indiana, 299
Archaeology, Marion County, Indiana, 53
Armacost, R. R., 103
Arthropod, infestation of man by, 298
Ascaris lumbricoides var. *suum,* ova of, 323
Ascites tumor cells, in vitro cultivation of, 87
"Ask the Biologist," 103
Asters, 104
Attitude, measurement, toward effective teaching, 292
Authors, directions for, 23, 331
Azeotropes, composition, 144
Aztec corn festival, 52

Bacteriology division, 63
Baker, P. C., 292
Ball State, thirty-four years of science at, 279
Barber, S. A., 223
Barton, T. F., 250
Beech Creek limestone, 223
Beetles, water, 207
Bell, R. L., 297
Benkeser, R. A., 167
Berberian, J. A., 320
Berg, P. W., 211
Bibbins, F. E., memorial, 34
Bieber, C. L., 228
Billman, J. H., 158
Biologists, work of, 103
Blair, H. W., 292
Blair, W. B., 225
Bloom, W. W., 139
Blume, H., 226
Botany Division, 98
Bracken, L. E., 256
Brain injuries, effect on sensory motor capacities, 295
Brazil, a regional interpretation, 224
Brooker, R. M., 145
Bryophyta, studies in Indiana, 122
Bud-break in woody plants, 103
Bumblebees, the domestication of, 278
Burdick, A. B., 279
Buser, F. B., 101

Cabbage maggot, 170
Cable, R. M., 298
Caird, R. S., 290
Calumet region, sequent occupance, 223
Campanularia, regression and replacement of hydranths, 297
Canright, J. E., 105
"Catface" peaches, 170
Carbohydrate metabolism, 64
Cations, qualitative analysis, 145
Caulobacter, 65
Cell cultures, long-term; applications of, 87
Cells, mammalian, long-term cultivation of, 87
Cerebral palsies, 295
Ceremonies, agricultural, in Peru, 52
Chandler, L., 129
Characeae, 107
Chemistry division, 144
Chemistry, symposium on teaching, 166
Chemists, training in safety, 144
Choerostrongylus pudendotectus, 319
Christens, J. M., 145, 150
Christy, O. M., 279
Chromatography, in quantative determination, 145
Cicada in Indiana, 203
Cinephotomicrography, 67
Cities, Indiana, 250
Claytonia, 102
Coal mine spoil banks, 99
Coleman, R. M., 321
Coleoptera: Dytiscidae, 171
  Hydrophilidae, 207
Colorimetry, copper determination by, 156
Committees of the Academy, 6
Conglomerate, Mansfield sandstone, 228
Constitution, Indiana Academy of Science, 19
Contacts, bridge transfer in electric, 291
Contributors, instructions for, 23, 331
Cooper, R. H., 279

Copper, a reagent for, 156
Corn, Indian varieties of, 104
Corn festival, Aztec, 52
Corn root tips, ability to respire sugars, 98
Cottingham, J. O., 143
County records for plants, 108
Croplands, Indiana, 256
Crowell, S., 297
Culture, applications of plant tissue, 81
Current directions, Mansfield sandstone, 228
Cyanide on *Ascaris* ova, effect of, 323
Cyto-genetics of Asters, 104

Daily, F. K., 107
Daily, W. A., 6, 10, 18, 98
Davis, J. J., 176
Davis, R. L., 181
DDT, experiments on resistance in *Drosophila melanogaster,* 211
Deam, C. G., 108
Deay, H. O., 203
Delisle, A. L., 104
Den Uyl, D., 99
Dichloro-argenate ion, dissociation constant of, 144
Downie, N. M., 293
Driver, H. E., 56
Drosophila, an Indiana microsporidian parasitic on, 297
Drosophila melanogaster, experiments on resistance to DDT, 211

Ebert, J. D., 72
Ecology, organic terrain, 98
Edington, W. E., 287
  necrology for 1952, 34
Education, attitudes toward public, 295
Edwards, P. D., Presidential address, 45
Electrical contacts, bridge transfer in, 291
Elliott, F. R., 299
Embryo, early chick, the development and role of PABA in, 72
Embryology of *Tripsacum dactyloides,* 104
Employee selection, 293
Entomology division, 170
Everly, R. T., 217

Factor analysis, personality, 294
Farquharson, L., 104
Fillers, of rubbers, 150
Filter-paper disc assay, 65
Fischer, R. B., 160
Fisher, D. J., 160
Fisher, T. R., 106
Flora, Indiana, 106
Forest succession, 100
Forest survey, Laughery Creek, 129
Friesner, R. C., 108, 278
Fungi of Marion County, 143
Fungus antibiosis, a short history, 278
  significance in medicine and industry, 278
Fungus sclerotia, 101

Gabriel Synthesis, 158
Gaillardia, 107
Gentilcore, R. L., 272
Geography, regional, Brazil, 224
Geology and geography division, 223
Geology of streams, 244
Geomorphology, Mohawk region, 226
Germanium spark spectrum, 291
Girton, R. E., 98, 281
Goldschmidt, E. P., 64
Gould, G. E., 170
Gross, E. W., 169
Grula, E. A., 65
Guard, A. T., 102
Guernsey, F. S., 101, 102
Guthrie, N., 168

Haemonchus contortus, development, 320
Haenisch, E. L., 166
Hagen, C. W., Jr., 81
Hardwood tree planting on coal mine spoil banks, 99
Hartsell, S. E., 63
Headlee, W. H., 298
Heal, W. E., Indiana pioneer mathematician, 287
Heath, E. C., 64
Heiser, C. B., Jr., 106
Heliopsis, 106
Helium, 290
Helmen, V. R., 53
Hemoglobin, synthesis in the chick embryo, 72
Hepaticae of Indiana, 136
Herbicide, 100
Highway patterns in Indiana, 266
Hire, C., memorial, 35
Histochemistry, ascorbic acid, 321
History of science division, 277
Hoehn, M. M., 64
Hollis, N. S., 294
Homicide, records given by suicidal and homicidal subjects, 296
Honey bees, pollen, 114
Howland, W. E., 278
Huddleston, C. M., 290
Hull, R. N., 87
Hurlbut, F., 266
Hurlbut, Z., 279
Hydrology, Indiana, 244
Hylemya brassicae (Bouche), 170
Hymenolepis nana var. *fraterna,* 321

Indiana, bryophytes, 122
Indiana flora, 106

Indiana harvests 1926-50, 256
Indiana Junior Academy of Science, 28
Indiana plant distribution, 108
Indiana, pre-Cambrian rocks in, 234
Indiana scientists, 277
Indian trails in Indiana, 266
Indian varieties of corn, 104
Indian village sites in Indiana, 266
Indians, North American, 56
Infectious viral particles, 95
Infestation, some unusual Arthropod cases of, 298
Insecticides used on alfalfa, 181
Insects of Indiana, 176
Insects, taxonomy, 172
Insects which "catface" peaches, 170
Isomer, Rb^{84m}, 290

Jacobs, M. E., 171
Jordan, E. T., 295

Karst topography of Puerto Rico, 225
Kessel, W. G., 147
Kirk, R. B., 295
Klenner, J., 318
Kline, D. R., 171
Knight, P. L., 319
Koffler, H., 64
Kossack, C. F., 65
Kottlowski, F. E., 234
Kuster, R. J., 103

LaCroix, J. D., 100
Lakes of Indiana, Lake Wawasee phytoplankton, 98
Lamprey, larval, 318
Langston, R., 101
Laughery Creek valley forests, 129
Lee, C. O., 278
Legume insects, 217
Leopold, A. C., 101, 102
Leopold, C. A., 103
Lesser clover leaf weevil, 217
Liming, A. N., 100
Lindsey, A. A., 6, 98
Lipscomb, R., 106
Liverworts, notes on Indiana, 136
Longitudinal vibrations in a hollow metal tube, 291
Lungworms, swine, 319
Lysozyme and gram positive bacteria, 63

Mackell, J. F., 277
Mackenzie Basin, Canada, ecology, 98
Magicicada septendecim, 203
Magnoliaceae, 105
Mahin, E. G., memorial, 37
Mammalian viruses, 92
Mansfield sandstone, 228
Manufacturing, intra-city, 225
Manuscripts, preparation of, 23, 331
Marion County, archaeology, 53
Market areas, 225
Marshall, G. E., 170
Marsilea quadrifolia, 139
Marsilea sporocarps, germination, 139
Martin, E., 291
Mathematics, role of, 45
Matus bicarinatus, 172
Maxwell, T. J., 52
Meibohm, A. W., 156
Meissner, K. W., 291
Memorials:
  Francis Eugene Bibbins, 34
  Charles Hire, 35
  Edward Garfield Mahin, 37
  Alfred Peter Poorman, 39
  Harvey Wesley Rhodehamel, 40
  Ernest Rice Smith, 41
  Jesse Elmer Switzer, 43
Metabolism, oxidative, 64
Metastrongylus apri, 319
Metaphosphate, 65
Meyer, A. H., 223
Michaud, H. H., 6, 31
Microscopists, pioneer, 281
Miner, E. E., 98
Mine water problem, 147
Minutes, executive committee, 11
  general session, 17
  spring meeting, 9
Mitchell, A. C. G., 290
Mitchell, M. L., 244
Mizelle, J. D., 320
Mockford, E. L., 198
Mohawk region, geomorphology, 226
Monaco, L. H., 323
Montgomery, B. E., 200, 278
Mont Tremblant Biological Station, 106
Mosses, Indiana, 122
Moulton, B., 1, 6, 224
Moving, effect on adjustment, 293
Munsee, J. R., 207
Murray, R. G., 67
Myerholtz, L., 63
McGrain, P., 244
McGuire, J. M., 64
McKenna, F. S., 294
Nash, H. A., 145
Nitrogen, in tomato fruit abnormalities, 102
Nuclear Spectra, 290

Oak forests, 129
Obelia, regression and replacement of hydranths, 297
Odonata, mating behavior, 171
Odonata, 1951-1952, notes and records, 200
Organic terrain, plant communities on, 98
Origins, theories of, 277
Oscillographic method for study of solution behavior at radio frequencies, 160

Oxygen consumption of developing *Ascaris* ova, 323

p-Aminobenzoic acid in the chick embryo, 72
Parasites, infestation of man by arthropods, 298
Patton, J. B., 234
Peake, J. S., 144
Penicillium chrysogenum, 64
Pentatomid bugs, 170
Perceptual intelligence, 295
Performance tests, in motor handicapped cases, 295
Periodical cicada in Indiana, 203
Perry, T. G., 223
Personality measurement, 294
Personality traits, 294
Personnel psychology, 293
Peru, agricultural ceremonies in, 52
Pharmaceutical, American Association, 278
Photographs, Edward Garfield Mahin, 36
Photomicrography, 67
Photomicrography, pollen grains, 114
Photosynthesis, measurement by Verduin method, 105
Physics division, 290
Phytoplankton of Lake Wawasee, 98
Pine seedlings, effect of petroleum naphtha on, 100
Plant Distribution Records, 108
Plants new to Indiana, 108
Plant records, Parke and Fountain counties, 101
Plant succession on abandoned farm lands, 100
Poa pratensis L., water absorption, 104
Pollen analysis in Quebec, 106
Pollen, collected by bees, 114
Pollen morphology, 105
Ponds, effect of light intensity on growth of algae, 99
Poorman, A. P., Memorial, 39
Population, in Indiana, 250, 272
Porter, C. L., 101, 278
Potzger, J. E., 100, 106, 129
Powell, H. M., 6
Pratt C., 296
Pre-Cambrian in Indiana, 234
Pre-illumination, morphology and response in slit pea test, 103
Presidential address, 45
Prison, problems of a clinical psychologist, 294
Psocoptera, 198
Psychologist, clinical in a prison situation, 24
Psychology division, 202

Qualitative analysis of cations, 145

Rafinesque, 278
Rainfalls, Indiana's records to 1953, 230
Rasmussen, G. K., 104
Rb^{82}, Rb^{84}, nuclear spectra, 290
Red clover, mammoth, effect of weevil on seed yields, 217
Regression and replacement of hydranths, 297
Reinforcement of rubbers, 150
Remmers, H. H., 292
Resistance to DDT, experiments with *Drosophila melanogaster,* 211
Respiration, measurement by Verduin method, 104
Rhodehamel, H. W., memorial, 40
Riedhart, J. M., 103
Ripley County, 100
Rohrer, C. S., 144
Rorschach Test, 296
Rothwell, N., 102
Rubber reinforcement by fillers, 150
Russia, science, 279

Schizophrenia, social behavior of, 292
Schmidt, F. C., 167
Schockel, B. H., 225
Science and a Free World, 279
Science at Ball State, 279
Science, role of mathematics in, 45
Science, Soviet Russia, 279
Sciences, sketches of their local development, 277
Scientific contributions made 1870-1950 by Indiana Colleges and Universities, 277
Scientific method, the, 278
Sclerotia, fungus, 101
Seaman, D. E., 105
Sequent occupance study, 223
Seymour, K. M., 144
Shaver, R. J., 325
Sheep stomach worm, development, 320
Silver chloride, complex formation from, 144
Sitler, L., 64
Slit pea test, Pre-illumination, morphology and response, 103
Smashey, A. R., 145
Smith, A. G., 52
Smith, D. M., 102
Smith, E. R., memorial, 41
Snowfalls, Indiana's records to 1953, 230
Soil type, 223
Solution behavior at radio frequencies, 160
Soviet Russia, science, 279
Spayth, F. J., 291
Spiders, Indiana, 299
Starch, agar, 65
Stark, E., 65
Starvation, effect on corn root tips to respire sugars, 98

Steigert, F. E., 290
Stoutamire, W. P., 107
Streptomyces venezuelae 8-44, 64
Strip mines, planting, 99
Suicide, records, 296
Sulfonamides, effect on chick embryo, 72
Switzer, J. E., memorial, 43

Taxonomy, discussion of, 172
Taxonomy in Indiana, 278
Taxonomy, pollen grains, 114
Teaching, attitude toward, 292
Teaching, symposium on teaching of chemistry in secondary schools and colleges, 166
Temperature, effect of —10° and —16°C. on *T. spiralis* larvae, 325
Temperature, Indiana's records to 1953, 230
Test holes in Indiana, pre-Cambrian rocks, 234
Tetrault, P. A., 65
Thomas, J. G., 101
Thompson, J. R., 99
Thompson, R. L., 92
Three-dimethylaminopropylamine, in copper determination, 156
Tissue culture, application of plant, 81
  newer methods and practical application, 87
  time lapse cinephotomicrography, 67
  virus particle counts in, 95
Tomato, abnormal fruits, 102
  fruit-set, 101
Tragopogon, 102
Transfer, bridge transfer in electric contacts, 291
Trematodes, Puerto Rico, 298
Trichinella spiralis, 325
Triphenyltetrazolium chloride, effect of antibiotics on bacterial reduction of, 63
Tripsacum dactyloides, embryology, 104
Tropisternus, biometrical studies, 207

Universe, origin of, 277
Urban geography, 225

Veratrum album, 145
Verduin method, use of, 105
Vibrations, longitudinal in a tube, 291
Viruses, factors affecting growth in vitro, 92
Visher, S. S., 230, 277
Vitamin C, 321
Volutin, 65

Wachholz, P. F., 224
Wagner, K. A., 136
Wallace, A., 99
Water problem in a mine, 147
Waterways in Indiana, 266
Weather forecasting, 224
Weather, Indiana's, some extremes and advantages to 1953, 230
Weather prophet, 224
Weatherwax, P., 52, 104
Weaver, E. E., 166
Weaver, R. H., 65
Weed killer, 100
Weinberg, E. D., 63
Weiss, E., 95
Welch, W. H., 122
Welcher, F. J., 6
Wellerson, R. J., 65
Westmeyer, P., 100
Wilson, M. C., 181
Woody plants, bud-break in, 103

Young, F. N., 170, 172
Young, R. N., 225
Youse, H. R., 114
Yuncker, T. G., 108

Zoology division, 297